

# Analysis of Foraging Behavior of Cattle Using a Wearable Camera under Diverse Vegetation

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**Key words:** Bite coding, Bite size, Direct observation, Grazing experience, Wearable camera

## Abstract

Although it is important to estimate the ingested plant species and the amount of forage intake by grazing animals, recording these items at the 1-bite scale has been difficult under diverse vegetation. Recent research confirmed that a small and inexpensive wearable camera is useful to determine ingested plant species and their proportion in total bites with high accuracy. In this study, we attempted to generate bite codes for cattle under diverse vegetation using wearable cameras. We used two cows which had a grazing experience in the previous year (GE) and the other two which had no grazing experience (NE). They grazed on a mountainous area (3 ha of sown pasture and 17 ha of forest) from late spring to mid-summer. A wearable camera (Panasonic HX-A500, 185 g) was fixed on the right cheek of the cows. Foraging behavior was continuously recorded for 120 min during morning foraging bouts, and direct observation was also conducted simultaneously. Bite codes were generated based on the morphological characteristics of ingested plants and the characteristics of foraging manner of the cows. Bite codes were classified into A (>100 cm), B (100–60 cm), and C (<60 cm) based on foraging height, then further classified into 5 types in A, 4 types in B, and 16 types in C (total 25 types) based on the differences in feeding manner. NE cows showed more frequent occurrence of the codes with low bite size than GE cows when foraging at a height of B in immediately after the start of grazing season. The results suggest that bite codes reflect bite size and thus can provide a precise understanding of their foraging behavior. It was also suggested that changes in bite codes due to the accumulation of grazing experience may affect foraging efficiency of grazing cattle.

## Introduction

Grazing herbivores select ingested plant species and their morphological components such as leaves and stem in order to optimize nutrient intake, as well as minimize energy costs and intake of harmful phytochemicals. Biting behavior is the smallest scale in the plant-animal interaction hierarchy, which influences dry matter intake and animal performance (Bailey et al. 1996). Therefore, it is necessary to know the ingested plant species and the biting behavior in grazing animals.

It is known that plants' morphological characteristics influence biting behavior (e.g., bite size, bite volume, and bite area) of grazing animals (Benvenuti et al. 2006). In diverse vegetation, since there are many plant species with different morphological characteristics, diverse manners of foraging emerged in grazing animals, which makes difficult the understanding of the foraging behavior of the animals. The creation of bite codes (i.e., the creation of bite categories) contributes to a simple and accurate estimation of the biting behavior of grazing animals (Dumont et al. 1994; Agreil and Meuret 2004; Bonnet et al. 2011).

Recording of biting behavior has long been carried out by direct observation to track individual animals. However, situations often arise in which the observer is unable to confirm the details of a biting, such as when the animal is foraging in a bush and biting several different plant species at the same time. In recent years, small, inexpensive, high-performance wearable cameras have been available. We previously confirmed that the wearable camera is useful to record the foraging behavior of grazing cattle under diverse vegetation and that it was more accurate than direct visual observation by an observer (Futahashi et al. 2017). In addition, animals foraged the same plant species in different manners. Wearable cameras may have the advantage of recording more detailed foraging manner, in addition to determining ingested plant species, because they provide images from the animal's viewpoint. In this study, a wearable camera system was used to create bite codes for grazing cattle.

## Methods

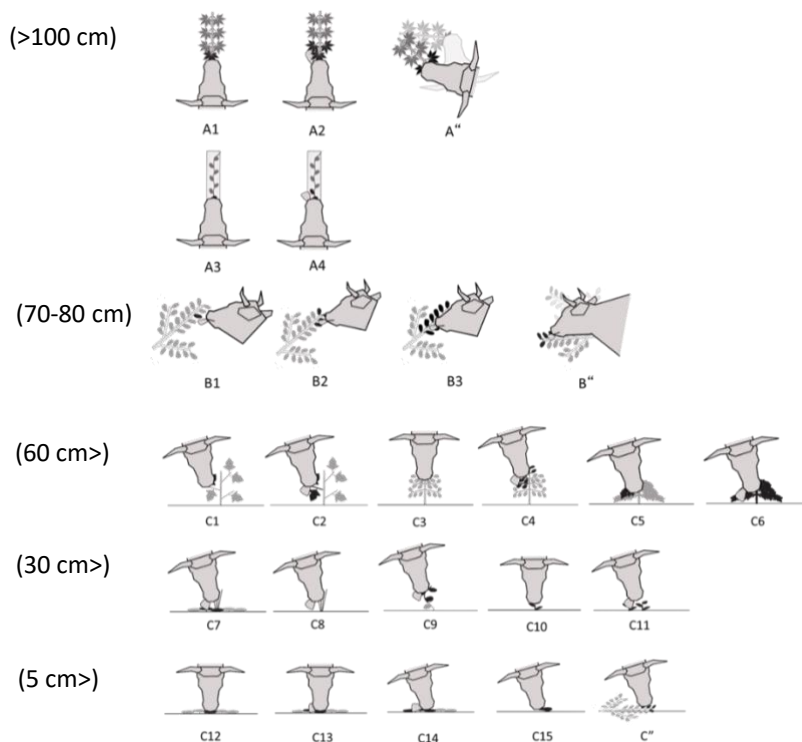
Six Japanese Black cows and two Japanese Shorthorn cows (weighing  $532.6 \pm 73.5$  kg/head, with a muzzle width of approximately 8 cm) grazed in a mountainous pasture (a grazing area consisting of 3.1 ha of sown pasture and 16.9 ha of forest) from May 16 to July 7, 2017. Among the grazing cattle, two Japanese Black

cows with and without grazing experience were selected as focal animals ( $n=4$ ). A wearable camera [Panasonic HX-A500, 94 mm (H) x 60 mm (W) x 27 mm (H), 185 g] was fixed on the right cheek of the cows so that the tip of the camera was 20 cm from the rhinarium. The foraging behavior was continuously recorded for 120 min during the morning foraging bout (6–9 am). Immediately after the start of grazing in May 17–30 (Day-2, 4 and 15), foraging behavior was recorded by using a wearable camera mainly in the forest area to compare the foraging manner of woody plant species between the individuals which had a grazing experience in the previous year (GE) and other two which had no grazing experience (NE). Foraging behavior was also recorded in both pasture and forest on June 15–16 and June 22–23, using the wearable cameras. At the same time, direct observation was conducted to obtain data on foraging behavior. Data obtained with the wearable camera were imported into a personal computer and played back using video editing software (Power Director 14. CyberLink, Tokyo, Japan) to determine the presence of bites based on the reduction of vegetation, mouth movements of the animals, and sounds of biting. Using these recordings, bite codes were generated based on the morphological characteristics of the ingested plants and the visual characteristics of the bites. Grasses and broadleaf herbs were classified according to the bite categories described by Bonnet et al. (2011) and Carvalho (2013). Because the classification of bite categories varies depending on the vegetation in the study area, we created new bite categories for woody species and broadleaf herbaceous species that did not follow the bite categories described in the previous studies by both direct observation and video images (15 minutes each in the morning and afternoon of the foraging behavior of two focal animals in the forest area).

Based on direct observation and video images from the wearable cameras, bite codes were classified as A (>100 cm), B (100–60 cm), and C (<60 cm) according to the foraging height; bite codes A and B were observed when the cows foraged upper layer plants above the animal's head in the standing resting position (Figure 1). On the other hand, the bite code C was observed when the animal lowered its mouth to forage on plants growing on the ground. Code A was divided into 5 codes and code B into 4 codes. In code C, we further divided the category according to the plant height because the edible parts of the plants varied with their height and morphology (6 codes at 60–30 cm, 5 codes at 30–5 cm, and 5 codes at 5–0 cm), resulting in a total of 25 categories. Even though the morphological characteristics of the plant species were the same, we observed a large difference in the amount of plant material ingested by grazing cows at one bite, thus we added bite code types according to their foraging manner. For example, A1, A3, B1, and C1 are bite categories that were considered to have a low bite size, where only one leaf was ingested from plants with the respective morphological characteristics. In addition, immediately after the start of grazing, the 3 following foraging manners were observed in addition to the 25 categories already created: "foraging on branches and leaves overhead while shaking the head" (A"), "foraging on leaves while placing the head on the branch from the trunk side toward the branch tip" (B"), and "foraging on leaves remaining on the branch that was broken off during eating and fell to the ground surface" (C"). These 3 foraging manners were observed regardless of grazing experience. Therefore, these foraging manners were further added to the code.

## Results and Discussion

In this study, bite categories for grazing cattle were created by video images from wearable cameras. There has been a study in which bite codes were created by attaching wearable cameras to goats to monitor their feeding behavior (Yayota et al. 2017). In grazing cattle, on the other hand, González-Pech et al. (2014) have created bite categories by direct observations, creating bite codes for woody plants, vines, and fruits. Compared to goats, cattle may have a wider range of feeding targets due



**Figure 1. Bite code created in this study.**  
Black color parts represent ingested plant parts by the cow.

to their larger body size and mouth. In addition, there are morphological differences in the buccal cavity between cattle and goats, especially in the tongue, which is developed only in cattle, and the bite code is different from that of goats because they have developed a different foraging behavior.

The frequency of occurrence of each bite code differed greatly among individuals, and grazing cows foraged on plants distributed in various positions under diverse vegetation with different manners (Table 1). The video images from a wearable camera indicated that even when foraging on the same plant species, the bite size varied greatly depending on the way of approaching the plant species and plant part. Although it is possible to determine the plant species foraged and estimate bite size to some extent by direct observation, the wearable camera can accurately record the foraging plant species and its part, and thus it may be possible to consider changes in nutrient intake depending on plant part.

**Table 1. Frequency of observation of each bite code in the GE and NE cows after the start of grazing.**

Bite code	Grazing experienced (GE) cows						Non-grazing experienced (NE) cows					
	Animal A			Animal B			Animal C			Animal D		
	Day-2	Day-4	Day-15	Day-2	Day-4	Day-15	Day-2	Day-4	Day-15	Day-2	Day-4	Day-15
A1	1	3	0	1	2	0	2	1	0	10	0	0
A2	10	60	0	0	11	1	2	12	3	0	19	2
A3	19	6	8	0	46	9	16	112	40	79	46	60
A4	0	0	3	0	1	0	0	4	15	10	2	2
B1	8	27	18	6	50	7	15	71	8	23	58	32
B2	69	96	19	24	150	6	37	58	19	15	11	36
B3	1	6	2	1	8	1	10	6	8	2	1	27
C1	0	24	1	0	7	4	0	17	5	5	2	12
C2	4	6	0	0	1	9	0	11	3	0	2	7
C3	30	79	8	3	172	3	65	186	19	51	152	9
C4	43	31	3	2	59	3	6	20	12	2	9	10
C5	0	1	3	0	1	9	0	2	3	0	11	19
C6	1	7	3	0	1	6	0	8	13	1	1	15
C7	2	19	57	0	3	0	0	5	7	2	24	26
C8	36	421	559	0	111	8	25	66	147	69	441	411
C9	0	2	3	0	0	0	0	1	9	0	0	30
C10	54	140	92	3	67	117	20	14	80	3	29	169
C11	21	5	1	0	1	2	4	0	0	1	0	3
C12	0	29	82	0	47	48	0	25	26	16	41	265
C13	2	35	32	0	3	17	0	8	4	38	10	8
C14	0	0	2	0	0	0	0	0	0	0	0	2
C15	0	0	0	0	0	0	0	0	0	0	0	0
A''	0	0	0	0	2	0	13	13	0	2	0	0
B''	0	0	0	0	0	0	0	0	0	2	0	0
C''	0	0	0	0	0	0	0	0	0	0	0	7
Total	301	997	896	40	743	250	215	640	421	331	859	1152
Foraging time (min/h)	40	60	60	20	60	20	30	50	30	35	60	55

In this study, we also confirmed differences in the foraging manner of cattle depending on grazing experience (Table 1). When cattle are not acclimated to the environment of the grazing area, it may be difficult for observers to directly observe their foraging behavior through individual tracking. In such cases, a wearable camera survey may be effective.

This study indicated that the cows with no grazing experience foraged in a less efficient foraging manner on woody plants. For example, NE cows showed more frequent expression of the codes for foraging on leaves and branches at a height (>60 cm) (e.g., code A1, A3 and B1) immediately after the start of grazing than GE cows, which is inferred to have a low bite size. In addition, the 3 bite codes of A'', B'' and C'' were mostly expressed in the NE cows. This result suggests that foraging of woody plants changes during the acclimation process and that foraging efficiency increases as grazing experience increases.

## Conclusions

In this study, we created a bite code that reflects bite size in different foraging manner of grazing cattle. This could be used to precisely determine the plant intake of grazing cattle under diverse vegetation. It was also

suggested that changes in the bite code with the accumulation of grazing experience may affect foraging behavior at a bite scale and feeding efficiency of grazing cattle.

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