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Giraffes like it hot? Research on giraffe drinking behaviour in response to warm water supply in a cold environment

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Abstract

Keeping giraffes in cold environments in zoos may place a burden on them. This study aimed to improve giraffe husbandry in cold environments by supplying warm drinking water in addition to a normal, ambient temperature water trough. Observations were conducted on three reticulated giraffes *Giraffa camelopardalis reticulata* kept at the Kyoto City Zoo during the winter (November–March) in 2019–2021, for 114 h. Control and warm water periods were alternated, with at least 4 days between them to ensure independence. Observations took place on 10 and 9 days for the control and warm water periods, respectively. The warm water was adjusted to approximately 37°C and supplied in a container (2 m high) in the outside enclosure. Behaviour was observed simultaneously via instantaneous sampling (foraging, rumination and others) and 1-0 sampling (branch foraging, rumination, oral behaviour and drinking), both at 1-min intervals. In the warm water period, total drinking frequency significantly increased and the frequency of drinking cold water significantly decreased. The number of times the giraffes drank during the hours shortly after the warm water was provided (0900 and 1300) also significantly increased. The average amount of warm water consumed per 7 h by the three animals was 69.16±9.54 L. No significant differences were observed in leaf foraging between the control and warm water periods. However, a significant or marginal increase in foraging behaviour was detected in two of the three giraffes during the warm water period. Thus, provision of warm water in cold environments may increase drinking by giraffes, and may contribute to management aiming to mitigate negative effects of cold in this species.

Introduction

Giraffes *Giraffa camelopardalis* are kept in various environments at zoos worldwide for conservation, education and other purposes. To achieve these objectives, zoo technicians have used various innovations to improve the environment in which giraffes are maintained, such as introducing enrichment feeders (Fernandez et al. 2008) and increasing the forage portion of the diet (Monson et al. 2018). The giraffe is native to sub-Saharan Africa (Muller et al. 2018). It has been suggested that keeping giraffes for prolonged periods in cold environments may be challenging for their physiology (Clauss et al. 1999). Previous studies on giraffe necropsies in different temperate regions have shown that loss of fat tissue (lipoatrophy) is a frequent cause of death, and exposure to low temperatures is among the suspected related causes (Clauss et al. 1999; Potter and Clauss 2005; Yong 2010). As a consequence, minimum indoor temperature recommendations of 16°C were made for giraffe husbandry (EAZA Giraffe EEP 2006). In addition, giraffes by nature have a diet based on tree leaves (e.g. Ciofolo and Pendu 2002; Lamprey 1963; Parker and Bernard 2005). Facilities keeping giraffes in the temperate zone experience challenges to provide suitable forage to their animals because leaves are lost from deciduous trees in winter (Okabe et al. 2022). Giraffes are reportedly dependent on fresh vegetation for water intake (Dagg 2014), and the loss of tree leaves may affect their water intake.

Providing warm water to giraffes kept in cold environments may help improve the zoo environment at low ambient temperatures. The present study incorporated the findings of studies on other ruminants to address this issue in the giraffe's zoo environment. For example, research on the temperature of drinking water for cattle *Bos taurus* in cold environments suggests that providing warm water may increase body temperature (Golher et al. 2015). Studies on drinking and water temperature show that cattle prefer warm water to cold water regardless of the season (Osborne et al. 2002; Wilks et al. 1990). Hydration is very important for ruminants (Gordon 1965) and probably also for giraffes. Water plays an important role in ruminant physiology, including prevention of overheating (Bianca 1964), salivation (pH regulation) and regulation of osmotic pressure in the ruminant stomach (maintaining the environment for ruminant microorganisms) (Silanikove 1992). The National Research Council (2001) reported a positive relationship between water intake and dry matter intake. Water deprivation reduces the foraging of ruminants (Burgos et al. 2001; Langhans et al. 1991). In domestic cattle, previous studies have shown that a temperature-humidity index (THI) of 67.2 is the critical point above which water intake increases and below which it decreases (Arias and Mader 2011).

Studies on drinking water in wild giraffes have shown that some individuals drink large volumes of water while others do not drink at all (Foster and Dagg 1972). Giraffes are thought to be resistant to dehydration because they can supplement their water needs by ingesting fresh plants (Dagg 2014). The husbandry manual of the European Association of Zoos and Aquaria (EAZA Giraffe EEP 2006) states that giraffes can drink 7.5 litres per day. However, a study conducted in a zoo reported that one adult individual drank approximately 45 L of water per day in a hot environment (Dagg 2014). Husbandry manuals published by the Association of Zoos and Aquariums (Burgess 2004) and EAZA (EAZA Giraffe EEP 2006) pay little attention to the drinking environment of giraffes, as they only set a minimum standard that water should always be available. However, it is unclear whether a cold environment affects drinking of giraffes. Therefore, this study was conducted to obtain new information on the drinking of giraffes in cold environments and assess whether the provision of warm water increases their water intake.

Materials and methods

Animals and housing conditions

Three unrelated reticulated giraffes *Giraffa camelopardalis reticulata* (two females and one male; Table 1) were observed in a mixed exhibit at Kyoto City Zoo, Japan. This exhibit harbours three giraffes and three Grevy's zebra *Equus grevyi* (one male and one mother-calf pair), and is surrounded by a fence and visitor area (for details see Okabe et al. 2022). There is a viewing aisle to the northwest of the exhibit, which allowed for observation of the giraffes from a height of approximately 3.5 m, making it possible for one person to observe all three individuals simultaneously. The giraffes were exhibited in the outside enclosure from approximately 0900 to 1600 and housed together indoors at night. The average temperature in Kyoto from November to March ranges from 5 to 13°C, with some days below EAZA's (EAZA Giraffe EEP 2006) recommended standard (12°C). The zoo did not have a clear minimum temperature standard for the outdoor release of giraffes; however, if individuals were shivering due to the cold, they were put indoors (which was not the case on the days of observation).

When the giraffes were allowed in the outside enclosure, they were provided with dry lucerne hay for ad libitum consumption and a restricted amount of hay cubes, in addition to the food provided as browse. Within the inside enclosure, dry lucerne hay, hay cubes and dry pellets (Mazuri® Wild Herbivore Diet Hi-Fiber) were offered in restricted amounts; however, the hay was never completely consumed during the night. The inside enclosure was provided with the same cold water for drinking as the outside enclosure.

The giraffes could drink freely from the drinking bucket (polycarbonate, 12.7 L; Figure 1a) and pond in the outside enclosure. Also, they would lick puddles of water that had formed on fences or on equipment. The buckets were filled with water whenever empty (usually 1–2 times a day); however, in winter, water was supplied less than once a day. The water temperature in the drinking bucket averaged 2.25±2.42°C and in the pond

Table 1. Individual characteristics of the three giraffes observed in the present study (in 2019–2021).

	Name	Sex	Birth date	Arrival date at Kyoto City Zoo
Female 1	Mirai	F	24 March 2001	25 October 2005
Female 2	Mei	F	18 May 2013	10 November 2014
Male	Ibuki	M	6 April 2017	26 June 2018

averaged 4.00±1.63°C (the water temperature was recorded before the giraffes were released). The water in the buckets was from a tap water source, whereas the pond was from a river water source. The water volume in the puddles was low, making it difficult to record the water temperature.

The provided browse varied daily. Browse was set up at eight fixed locations along the fence in the outdoor enclosure and was attached using chains. Only one plant species was used per location at a time. The tree species used include bamboo-leaf oak *Quercus myrsinifolia*, locust tree *Robinia pseudoacacia*, red bayberry *Morella rubra*, and glossy privet *Ligustrum lucidum*. Of these, only *R. pseudoacacia* is deciduous, and its bark was fed to the giraffes. Approximately 10 kg of branches of at least three of these tree species were provided during the day. The zoo has followed this feeding practice for the past 10 years as part of its giraffe husbandry management. All three giraffes were under this feeding management plan for at least nine months.

Experimental procedure

Control periods were from 30 November 2019 to 16 January 2020 (7 days); 13 February to 19 February 2020 (4 days); and 17 December 2020 to 10 January 2021 (6 days). The warm water supply periods were from 21 January to 4 February 2020 (5 days); 27 February–7 March 2020 (4 days); and 14 January–29 January 2021 (4 days). During the warm water supply period, warm water was provided to the giraffes daily. Each period was spaced at least four days apart to avoid the influence of treatments on each other. A three-day acclimation period was included before the start of the warm water supply observation and a three-day period without warm water before the start of the control period observation. Observations were made every one to five days. Observations on rainy days and during the females' oestrus were removed from the final dataset because of their potential effects on behavioural trends. Days when additional branches were added to the regular browsing enrichment were excluded from the observation data because the number of branches and leaves fed affected the behaviour of giraffes. In addition, one of the observed individuals (Mei, F2) gave birth on 10 February 2021. Data from two weeks prior to the birth were excluded because the period close to birth may affect foraging behaviour. As a result, the number of observation days covered was 10 days for control days and 9 days for warm water provision days. The zoo was open to visitors on all observation days. The observations were conducted by a single zoo staff member (first author), who wore casual clothing (not zoo staff uniform) to avoid affecting the giraffes' behaviour. Observations were made from visitors' areas using ISBOApp (Ogura 2013).

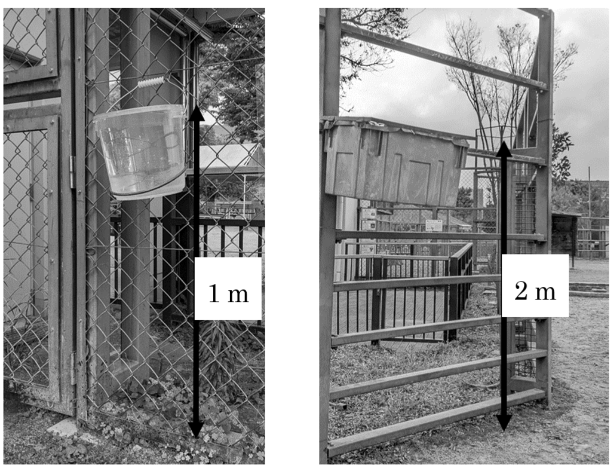

Figure 1. Photo of (a) water bucket (12.7 L) and (b) container (400×709×501 mm height×width×length) filled with warm water installed on the giraffe grounds. The bucket did not contain warm water during either period.

The warm water was carried in buckets from the hippopotamus *Hippopotamus amphibius* enclosure next to the giraffe enclosure and placed in a container (TK-110-GY, TRUSCO Nakayama Co., Japan; 400×709×501 mm, height×width×length) attached to the fence at an approximate height of 2 m (Figure 1b). The water temperature was adjusted to approximately 37°C. Warm water (60 L) was added to the container before releasing the giraffes at 0900, and another 40 L of warm water was added at 1320 to maintain the water volume. The volume of water remaining in the container was measured after observation. The temperature of the remaining water was not measured.

The temperature-humidity index (THI) was adopted as a temperature indicator in this study. THI was an important factor in daily foraging patterns in previous studies on livestock. This index was originally developed by Thom (1959) and extended to cattle by Berry et al. (1964).

The THI was calculated according to the following model, using the method described by Thom (1959):

$$THI=(0.8 \times AT + (RH / 100) \times (AT - 14.4)) + 46.4$$

where AT is the ambient temperature (°C), and RH is the relative humidity (%).

Temperature and humidity were measured with a digital thermo-hygrometer (HC-520, Shenzhen Huaye E-Commerce Co., China) placed in the shade in the visitors' area. Temperature and humidity were recorded 30 and 90 min after the start of each 2 h observation session and averaged to obtain daily, monthly and seasonal values. The THI values (six measurements) were averaged for each day and compared with the behavioural expression frequencies of the giraffes.

Observations were always made at 0900–1100, 1110–1310 and 1330–1530, using a combination of instantaneous sampling (i.e. noting the behaviour that occurred exactly at the pre-defined time) and 1-0 sampling (i.e. noting whether a specific behaviour had occurred at any time during the observation interval) (Crockett and Ha 2010). The 1-0 sampling is used for behaviours that have such a brief duration that their occurrence might be unreported in instantaneous sampling. Drinking was defined as placing the tip of the mouth on the water surface and sucking the water. In conjunction with this drinking, the drinking location (drinking bucket, pond on the ground or warm water container), branch foraging (including feeding sites: leaves, twigs and bark), rumination behaviour (including rumination while walking) and oral behaviour were noted if they occurred during a 1-min interval (1-0 sampling). To investigate the effects of changes in drinking on foraging and oral behaviour (stereotyped behaviour in giraffes), the main recorded behaviours were foraging (intake and mastication of a food item: browse, lucerne hay, hay cube, undergrowth), rumination (regurgitation, chewing and swallowing of rumen contents without walking) and oral behaviour. All other behaviours were recorded as "other". Five types of oral behaviours were recorded: fence licking (licking a non-food item, fences, walls and roofs, with their tongue), puddle licking (licking of puddles on fences and other equipment), wood licking (licking wooden equipment other than food with their tongue), wood gnawing

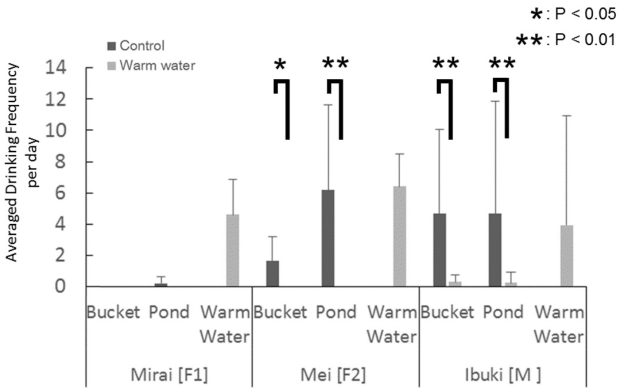

Figure 2. Comparison of the frequency of use of drinking water locations during the control and warm water periods. There was no presentation of a warm water container during the control period.

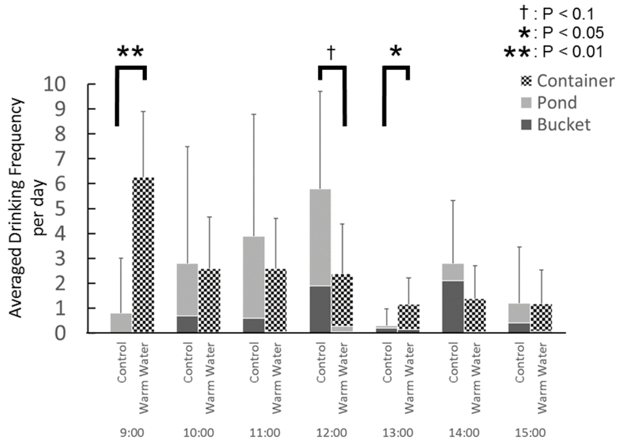

Figure 3. Change in drinking frequency per day by time of day.

(gnawing at wooden equipment) and tongue play (manipulating twigs and undergrowth in the mouth with their tongue). Within foraging behaviour, the food type (branch, dry hay, hay cube, undergrowth) being foraged was also recorded. Direct visual focal (instantaneous) sampling was performed at 1-min intervals to record the behaviour of all giraffes in the observer's field of view. Because drinking and oral behaviours have short expression bouts and rumination behaviours are expressed simultaneously with other behaviours such as walking, combined 1-0 sampling was adopted. All recordings were performed simultaneously on all observation days. Results from instantaneous sampling were expressed as a percentage of all instantaneous observations, and results from 1-0 sampling were expressed as a percentage of all bouts per day, for the statistical analysis. The ethics committee of the Kyoto City Zoo approved the study protocol (KCZ-2020-021).

Statistical analysis

The environmental temperature and THI differences between the control and warm water periods, and giraffe behaviour (including drinking frequency and branch feeding frequency) between the control and warm water periods were compared using the Mann-Whitney U test. All statistical analyses were conducted using Statcel4 (OMS Publishing, Saitama, Japan). All data are presented as means with 95% confidence intervals.

Results

There was no significant difference in the environmental temperature and THI between the control and warm water periods (environmental temperature control: 11.06±4.72°C, warm water: 11.30±2.82°C, P=0.87; THI control: 53.70±6.23, warm water: 53.47±6.23, P=0.62).

The average number of times each giraffe was observed drinking per day is shown in Figure 2. The mean frequency of warm water drinking observations per day was 4.83±2.24 times for Mirai (F1), 6.83±2.06 times for Mei (F2) and 5.56±2.30 times for Ibuki (M). The average consumption of warm water during the warm water period was 69.16±9.54 L per day for all three animals. Among the observed individuals, Mirai (F1) did not show any significant change in the frequency of using the drinking location due to the warm water supply. In contrast, Mei (F2) and Ibuki (M) significantly decreased their frequency of bucket and pond use (F2 bucket: P=0.003, pond: P=0.003; M bucket: P=0.0009, pond: P=0.008). The total number of drinks during the warm water period significantly increased for Mirai (F1) (P=0.0001) compared to the control period. The total number of times Mei (F2) and Ibuki (M) drank water did not change significantly (F2: P=0.48, M: P=0.74).

The total number of drinking bouts per time period is shown in Figure 3. In the control period, peaks were detected at 1200, whereas in the warm water period a peak was observed at 0900. When the two periods were compared, the number of drinks significantly increased at 0900 (P=0.001) and 1300 (P=0.049) and marginally decreased at 1200 (P=0.065) in the warm water period.

The frequency of behaviour observations in the two periods are shown in Table 2. There was no significant difference in leaf foraging between the control and warm water periods (F1: P=0.32, F2: P=0.22, M: P=0.10). Twig and bark foraging were also not significantly different (twig F1: P=0.54, F2: P=0.84, M: P=0.23; bark F1: P=0.65, F2: P=0.22, M: P=0.33). For Mirai (F1), only the foraging behaviour of hay cubes showed a marginal significant increase (P=0.09) during warm water supply. In Mei (F2), foraging behaviour increased (P=0.0003) and other behaviours decreased (P=0.03) significantly when warm water was supplied. In addition, among the oral behaviours, puddle licking behaviour showed a marginal decrease (P=0.09) and wood-chewing behaviour showed a marginal increase (P=0.09). There was a significant increase in foraging on non-branches (P=0.01), especially on hay (P=0.04) and hay cubes (P=0.02). In Ibuki (M), only rumination behaviour (by instantaneous sampling) increased significantly (P=0.004) when warm water was supplied. Hay cube foraging behaviour (P=0.06) marginally decreased, as did oral behaviour (P=0.06), licking behaviour (P=0.07) and puddle licking behaviour (P=0.09).

Discussion

The average amount of warm water consumed per 7 h period by the three animals during the warm water period was approximately 70 L. The amount of drinking water per adult giraffe in a previous study was 45 L per day (Dagg 2014). Although simple comparisons cannot be made, it is possible that the

Table 2. Comparison of the giraffes' behaviour during the control (10 days) and warm water (9 days) periods per day. Foraging is the sum of branch and non-branch, and items with (1-0) indicate recorded data from 1-0 sampling. Data presented as percentage of total behaviour expression per day.

Animals	Marai (F1)		Mei (F2)		Ibuki (M)	
Periods	Control	Warm water	Control	Warm water	Control	Warm water
Foraging	39.2±8.4	39.9±7.4	27.7±4.9	36.9±9.3 **	37.3±6.4	37.2±5.3
Branch	23.9±5.6	21.5±6.6	16.9±4.5	20.0±8.3	13.7±2.9	13.5±6.0
Leaves (1-0)	10.9±2.9	9.4±4.1	7.1±4.2	5.2±1.1	10.8±3.2	8.1±1.9
Twigs (1-0)	3.2±1.2	2.4±1.4	8.9±2.8	8.3±2.8	2.8±2.0	1.8±1.3
Bark (1-0)	16.5±6.1	16.0±7.9	7.6±4.4	10.9±3.9	7.3±4.7	8.4±4.0
Non-branch	15.3±5.0	18.4±4.2	10.8±3.4	16.9±5.1 *	23.6±6.9	23.7±5.0
Leaves (1-0)	8.8±3.6	10.9±4.0	3.9±3.2	7.3±3.2 *	18.3±7.3	19.8±5.2
Twigs (1-0)	5.5±1.8	6.9±1.2 †	6.0±1.3	8.4±2.4 *	4.6±1.5	3.4±1.1 †
Bark (1-0)	1.0±1.9	0.6±0.6	0.9±0.7	1.2±1.3	0.7±1.1	0.4±0.6
Drinking (1-0)	0.1±1.1	1.3±0.6 **	2.1±1.6	1.8±0.6	2.6±3.0	1.6±0.6
Rumination	13.1±4.8	12.0±5.3	14.6±5.3	12.4±5.8	6.1±2.2	9.8±2.7 **
Rumination (1-0)	17.8±4.3	17.3±6.1	22.0±4.0	19.3±4.6	19.5±5.9	19.4±5.3
Oral Behaviour	23.5±7.7	21.5±6.1	8.5±2.7	10.4±5.1	7.8±3.3	6.3±2.7
Oral Behaviour (1-0)	36.8±9.7	35.4±5.8	18.5±5.3	17.4±6.3	18.8±6.6	13.8±4.5 †
Licking (1-0)	17.7±9.3	17.7±5.7	6.1±1.2	4.8±1.7	6.7±2.0	4.8±2.4 †
Puddle licking (1-0)	1.5±1.7	1.1±1.9	3.1±3.7	0.8±1.6 †	2.7±3.3	0.6±1.0 †
Wood licking (1-0)	9.1±5.0	4.7±1.9	3.2±2.8	2.0±1.3	3.8±3.6	2.0±0.9
Wood gnawing (1-0)	8.4±8.6	11.6±6.4	5.6±4.3	9.4±4.7 †	4.9±4.0	5.6±2.3
Tongue play (1-0)	0.1±0.2	0.3±0.5	0.6±0.5	0.5±0.6	0.5±0.6	0.9±0.7
Other	24.3±4.6	26.5±6.1	49.2±7.5	40.2±7.9 *	48.7±6.6	46.7±4.8

amount of water consumed per animal per hour was greater than the amount of water consumed in the previous study. The drinking behaviour of giraffes during the control and warm water periods differed among individuals. Mirai (F1) showed a significant increase in the total number of times she drank during the warm water period. In contrast, this did not significantly change for Mei (F2) and Ibuki (M) during the supply of warm water. However, this does not mean that the warm water installation did not have any effect on drinking in these two animals. Drinking from bucket and pond by these two animals significantly decreased after the installation of warm water, and drinking from cold water supply points was almost non-existent. One thing to consider about this change is the shape of the drinking water containers. The shape of the buckets normally used by the giraffes for drinking water outdoors is very different from that of the warm water containers installed in this study. The different shape was chosen because cows prefer to drink more water from troughs with a larger surface area (Teixeira et al. 2006). This difference may have affected the giraffes' drinking behaviour. However, with respect to changes in the time of day for drinking, the number of times the giraffes drank water significantly increased at 0900 and 1300, shortly after the warm water was provided. This is an additional indication that the giraffes chose to drink warm water. This preference has also been observed in domestic cattle (Wilks et al. 1990). Cold water lowers the temperature in the stomach of ruminants, affecting the activity of gastric microorganisms, whereas warm water does not cause this and thus reduces energy loss (Bewley et al. 2008; Petersen et al. 2016). For these physiological reasons, giraffes may also prefer warm water. There was no significant change in the frequency of cold water supply point usage (bucket or pond) for Mirai (F1), most likely because of the low frequency of pond and bucket drinking in the control period. Since giraffes themselves are drought tolerant (Dagg 2014), it is possible that Mirai (F1) had no problem drinking less water during the day in cold weather.

The frequency of puddle licking was similar in both periods for Mirai (F1), and the behaviour of the other two animals changed marginally after the supply of warm water. The fact that this licking behaviour was reduced by the installation of warm water could complement drinking. Wild giraffes, particularly in Namibia's northwest, obtain their available moisture from forage and precipitation from fog which settles on the forage throughout the evening and early morning (Burgess 2004; Fennessy 2009). Prior studies on cattle in cold climates have shown that snow is ingested using their tongues when water is not available (Young and Degen 1980). In situations where only cold water is available, such as in cold climates, giraffes may have supplemented their water intake by consuming small amounts of water, such as that from puddles.

There was no significant difference in leaf foraging during the control and warm water periods, yet foraging behaviour tended to increase in two of the three animals. In particular, Mei (F2) showed a significant increase in her overall foraging behaviour. The breakdown showed a significant increase in foraging behaviour for hay and hay cubes. There was also a marginal increase in hay cube foraging in Mirai (F1). Previous studies on ruminants have reported a positive relationship between water intake and dry matter intake (National Research Council 2001). Therefore, this result supports the possibility that the installation of warm water increased water and dry matter intake in giraffes.

Conversely, Ibuki (M) showed a decreasing trend in hay cube foraging behaviour. This change could be because the number of hay cubes fed was fixed, and the increase in hay cubes foraged by Mirai (F1) and Mei (F2) would have resulted in a decrease in the amount of hay cubes available to be foraged by Ibuki (M).

Conclusion

It is unknown whether the provision of cold water to giraffes in cold weather limits their drinking water intake, but it is possible that the provision of warm water may have allowed them to drink more water and ingest more feed. The shapes of the normal water bucket and warm water installation container are different, so that an effect of the container shape alone cannot be completely ruled out. However, the increased use of warm water immediately after it was delivered suggests that the giraffes preferred this water for its temperature. Therefore, the supply of warm water in cold environments may improve the hydration status of captive giraffes, and may also affect their feed intake behaviour.

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