

The articles are arranged starting from investigations related to housing/inadequate conditions, then diet, then physiological factors, then hormones/genetics. Overlying these categories is the theme that tongue rolling behavior occurs in response to poor welfare, stress, and frustration in cattle.

Phillips, C. (2008). Behavioural Adaptation to Inadequate Environments. In C. Phillips (Eds.), *Cattle behaviour and Welfare* (pp. 208-216).

### **Summary:**

This chapter of the book is a summary of behavioural adaptation to inadequate environments in cattle. Previous knowledge in this topic established that keeping cattle in confined environments leads to a modification of their behaviour compared to wild cattle. Previously, domesticated cattle have been introduced into wild environments to observe their 'normal' behaviour. It was stated that farm animals such as cattle should be allowed to express these 'normal' patterns of behaviour to promote welfare.

This chapter compiles information from many sources to present an overall view on how confinement may cause frustration, boredom, and stress that can result in changes of behaviour to cattle. The author presents the physiological needs of cattle related to thirst, hunger, injury, disease, fear, stress, ingestion, motion, rest, etc. The author presents tongue rolling as a coping mechanism/response to disruptions in these listed physiological needs. These disruptions are described in the context of intensive housing situations. Restricted housing conditions decrease locomotion and result in larger and restricted diets. Tongue rolling behaviour occurs most often after feeding, which may provide evidence of oral stereotypies being related to diet. One of the main themes of this chapter is that oral stereotypies such as tongue rolling indicate an inadequate environment for the cattle. This means that cattle farmers should be aware of these behaviours, so that they may adjust the care of cattle to better meet the animals needs. Another important message is that stereotypies tend to be learned behaviours (not innate), so they should be considered as important indicators of the animals current environment. Phillips 2008 suggests that if tongue rolling is performed between 1%-5% of the cattle population, or if an individual animal is performing it for more than 10% of its life, then animal welfare is likely to be reduced.

### **Contribution:**

This article was included in the review because it provides a summary of existing literature regarding cattle stereotypies. This article used up to date literature (until 2008) to explain how inadequate conditions can cause problems to cattle, which manifest as tongue rolling behaviours. This article advances knowledge in the field by detailing the broad causes of tongue rolling behaviour.

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Wilson, L. L., Terosky, T. L., Stull, C. L., & Stricklin, W. R. (1999). Effects of individual housing design and size on behavior and stress indicators of special-fed Holstein veal calves. *Journal of Animal Science*, 77(6), 1341-1347. <https://doi.org/10.2527/1999.7761341x>

### **Summary:**

Previous literature had criticized cattle housing conditions because they involve tethering for long periods of time and restricted movements. This suggests that cattle may show abnormal behaviours and increased stress levels in confined housing. Previous knowledge had also determined stereotypic behaviours such as tongue rolling are indicative of stress. This led Wilson et al. 1999 to scan for oral stereotypies (tongue rolling) while also examining cortisol levels under different housing conditions.

This study involved videotaping 108 calves from 3 to 7 days old over the course of 18 weeks. Cattle were placed into 3 different housing conditions (small, medium, large). Blood samples were collected from cattle to isolate cortisol levels. Researchers kept the diet of all the cattle the same to minimize any effect of diet on oral behaviour.

Wilson et al. 1999 found that increased cortisol levels were observed over time with no significant differences between housing conditions. This indicates that tethering and housing conditions in general increase the degree of stress over time, regardless of the specific size of housing.

There were no significant differences observed in the behaviours of cattle tethered (tied up) in smaller housing vs larger housing. Tongue rolling was observed in all of the housing conditions. Tongue rolling behaviours did not significantly change over time. This indicates that cortisol levels alone are not directly influencing the expression of tongue rolling behaviour.

Tongue rolling behaviour may be related more to the existence of an environmental stressor such as confined housing rather than increasing cortisol levels over time.

Wilson et al. 1999 noted that the standard error within treatments were quite high, indicating high variability between calves. This study design could benefit from controlling for variability and other factors.

### **Contribution:**

This article provided evidence that confined housing conditions in cattle may be a source of stress over time as indicated by increasing cortisol levels and observations of tongue rolling behaviour. This article also provided evidence that the size of the housing condition may not be relevant to animal welfare when compared to whether the animal is tethered vs free to move on a pasture.

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Ishiwata, T., Uetake, K., Kilgour, R. J., Eguchi, Y., & Tanaka, T. (2007). Oral behaviors of beef steers in pen and pasture environments. *Journal of Applied Animal Welfare Science*, 10(2), 185-192. <https://doi.org/10.1080/10888700701313629>

### **Summary:**

Previous literature has determined that restricted feeding and housing are a common practice in cattle, which leads to abnormal oral behaviour. This also includes tethered cattle which have been shown to display greater levels of tongue rolling compared to pasture cattle.

Ishiwata et al. 2007 chose to investigate oral behaviours (including tongue rolling) of cattle in pen vs pasture environments to further the hypothesis provided in previous literature. This study observed 122 male cattle in eight pens, and 1136 male cattle at six pastures. The cattle were observed through scan sampling methods at each location throughout specific periods in the day. Pasture cattle were located in Australia and were able to feed freely by grazing throughout the day. Pen cattle were in Japan and had restricted diet as they were only fed at certain times. Previous literature found very little abnormal oral behaviour in male cattle. This study chose to exclusively investigate male cattle to observe the prevalence of tongue rolling, and whether tongue rolling is impacted by housing conditions.

Ishiwata et al. 2007 confirmed cases of tongue rolling in male cattle which contradicts with previous literature that had shown tongue rolling was only possible in female cattle. This study also determined that male cattle in pasture environment show less tongue rolling behaviour compared to cattle kept in pens. Overall, it was hypothesized that cattle in the pen environment experienced dietary frustration as a result of decreased time spent feeding throughout the day. The ability for the cattle to feed freely in an open pasture environment limited tongue rolling behaviour.

### **Contribution:**

This article provided evidence that restricted housing environments may decrease cattle welfare as a result of not being able to feed freely. This article is in line with previous literature explaining how frustration (in this case related to diet) causes tongue rolling. Further research can be done to assess the more specific causes for why pasture cattle with open diets perform less tongue rolling.

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Ridge, E. E., Foster, M. J., & Daigle, C. L. (2020). Effect of diet on non-nutritive oral behavior performance in cattle: A systematic review. *Livestock Science*, 238, 104063. <https://doi.org/10.1016/j.livsci.2020.104063>

### **Summary:**

This review article addresses previous research that has been done on tongue rolling behaviors in cattle, with a specific focus on dietary and nutritional causes. Ridge et al. (2020) discuss that previous literature has found dietary-based and housing factors stimulate non-nutritive oral behaviors such as tongue rolling. The prevailing theory of dietary causes to oral behavior is that restriction in the duration and frequency of feeding in cattle results in unfulfilled behavioral needs and frustration. Specially, it's thought that a high grain diet fed in confinement, high roughage diet, and large food particle sizes, result in reduced rumination time and gastrointestinal frustration, which leads to oral stereotypic behavior such as tongue rolling. This review used 3 databases (CAB abstracts, OVID, and SPAC) to assess which dietary components may impact tongue rolling behaviors. A total of 22 articles were used for this review.

The following dietary treatment types were found within the chosen articles: roughage inclusion, total feed amount, ingredient type, mineral addition, particle size, feed presentation, and rumen content. Of these listed treatments, only amount of roughage and grain had conclusive results in changing non-nutritive oral behaviors. 45% of studies found increased oral behaviors when the amount of roughage was restricted. When roughage is decreased, oral behaviors also decrease. Treatment types including ingredient type, particle size, feed presentation, mineral additional, and rumen content did not conclusively alter non-nutritive oral behaviours in cattle.

Ridge et al. 2020 suggest that roughage inclusion may be the most effective dietary strategy to reduce tongue rolling and oral behaviors in cattle. They suggest that these oral patterns may be a behavioral indicator of poor welfare. Further research should be conducted on the effects of different dietary treatments on non-nutritive oral behaviors because the literature on this topic is limited.

### **Contribution:**

This article summarizes the current literature to understand which dietary factors impact oral behavior such as tongue rolling in cattle. It identifies that only certain dietary components (roughage inclusion and grain level) conclusively impact tongue rolling behavior, while non-dietary factors (housing, social structure) also play a role. There are inconclusive and contradicting results for feed presentation, particle size, feed amount, or ingredient type, so greater amounts of research into these areas would give a better understanding. As a review, this article provides related literature that can be used for further research into tongue rolling behavior.

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Bergeron, R., Badnell-Waters, A. J., Lambton, S., & Mason, G. (2008). Stereotypic oral behaviour in captive ungulates: Foraging, diet and gastrointestinal function. In G. Mason, & J. Rushen (Eds.), *Stereotypic animal behaviour: Fundamentals and applications to welfare* (pp. 19-35).

### **Summary:**

This portion of the book examines how foraging and diet in captive cattle may contribute to oral behaviours such as tongue rolling. Firstly, the authors define tongue rolling behaviour as swinging the tongue outside the mouth from one side to another, or repetitively swinging the tongue inside the mouth. The authors noted that this behaviour is highly variable, as it can range between 1 to 38% of the time the cattle is awake. It's seen at its highest levels shortly after feeding, which lends support to the idea that tongue rolling may be directly related to feeding behaviour.

Bergeron et al. 2008 support previous literature as they agree that stereotypic behaviours such as tongue rolling act as coping mechanisms that address some deficit within the animal's lifestyle. The authors gathered previous literature to discuss how tongue rolling in cattle occurs as a result of changes in foraging, diet, and gastrointestinal environment when they are placed in captivity.

The authors state that cattle in captivity have an inadequate diet because it is too low in fiber and does not fill their gut. This leads to an unhealthy gut environment, which is supported by previous literature that states low fibre foods cause digestive problems and increased acidity within the gut of cattle. These disruptions in gut physiology prompts the cattle to perform tongue rolling behaviour.

Additionally, it was discussed that diets in captivity disrupt the natural pattern of feeding, by removing the ability to spend many hours a day foraging. Bergeron et al. 2008 consider the pasture environment the most "natural" feeding style for cattle because it allows for grazing. Captivity limits this grazing behaviour and restricts cattle to defined amounts of food and feeding schedules. This causes frustration as the cattle cannot meet their behavioural needs.

### **Contribution:**

This chapter does a great job of summarizing oral behaviors in captive cattle. This adds to the literature as it focuses in on pen/captive environment, and how that can cause frustration in the cattle. This article also makes the claim that pasture environments limit tongue rolling because it allows for more "natural" foraging.

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Biven, R. (2020). Tongue rolling stereotypy in cattle—etiological, epidemiological, and clinical investigations. *Bulgarian Journal of Veterinary Medicine*, 1-9.  
<https://doi.org/10.15547/bjvm.2336>

#### **Article summary:**

This article studied the causes and prevalence for the appearance of tongue rolling behaviour in Cattle and assessed whether tongue rolling behavior was associated with clinical parameters such as rectal body temperature, heart rate, respiratory rate, and rumen movement). Biven (2020) conducted this study by surveying cattle originating from 5 cattle farms from different regions of Bulgaria over a period of 2 years. Cattle were put into 2 groups, Group 1 (n=1055) control cattle and Group 2 (n=48) cattle that presented tongue rolling behaviour. Both groups were uniform in regards to age, breed, body condition, sex, and activity levels.

The results of the study show that the prevalence of tongue rolling behaviour is on average 4.6%. However, they also discovered that some cattle are more vulnerable to this oral stereotypic behaviour. Heifers (female cattle that had not had children) from the ages of 13 to 25 months had an average tongue play activity of 12.6%. Tongue rolling activity in cattle older than 25 months (n=638) was present at a low frequency of 0.8%. No tongue rolling activity was detected in male cattle or lactating cows. This presents a direction for future research (to establish reasons why tongue rolling occurs only in female cattle).

This study found no statistically significant difference between the 2 groups for the clinical parameters mentioned earlier. This suggests that tongue rolling behaviour is not associated with changes in heart rate, respiratory rate, rumen movement, or rectal temperature.

The prevailing theory presented in this study and previous literature suggests that the main cause of tongue rolling behaviour is a lack of environmental stimuli, specifically the deprivation of food and boredom. Biven (2020) suggests that cattle raised in a pasture environment rather than indoor stalls, allows them to feed frequently, limiting boredom and decreasing tongue rolling activity.

#### **Article contribution:**

This article was published in 2020, so it provides a recent insight into the tongue rolling behaviour. This study found that changes in heart rate is not associated with tongue rolling behaviour, which contradicts previous literature. Biven (2020) agrees with previous literature on the causes of tongue rolling resulting from decreased environmental stimuli. This study found certain population such as males do not display tongue rolling, which is an interesting topic for future study. This article does a very good job of providing previous literature that has investigated this topic, and what general theories exist for this behaviour.

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Seo, T., Sato, S., Kosaka, K., Sakamoto, N., & Tokumoto, K. (1998). Tongue-playing and heart rate in calves. *Applied Animal Behaviour Science*, 58(1-2), 179-182.

[https://doi.org/10.1016/S0168-1591\(97\)00062-2](https://doi.org/10.1016/S0168-1591(97)00062-2)

### **Summary:**

Previous literature has determined that tongue rolling behaviour in cattle is a response to poor animal welfare, stress, and frustration. It had been hypothesized that stereotypes function to reduce the high arousal that cattle may experience, but no literature prior to this study had been published to provide evidence for this hypothesis.

This study used 5 Japanese calves aged 6 months. All the calves were fed similar diets and had similar housing conditions. This was done to ensure that confounding variables would not interfere. A heart rate monitor was attached to each calf and monitored before, during, and after tongue rolling behaviour was observed. Researchers made sure to only use data for when the calves were not moving because movement alters heart rate.

Seo et al. 1998 determined that heart rate was significantly lower during tongue rolling behaviour compared to before or after. After tongue rolling was finished, the heart rate of cattle went back up to baseline (the same value as before the behaviour). This indicates that tongue rolling indeed has a de-arousal function, as it functions to decrease heart rate. Stress and frustration are known to increase heart rate, so these results suggest that cattle may use tongue rolling as a coping mechanism against elevated stress/frustration. Additionally, it was found that these results were especially apparent after feeding. This provides a potential link between tongue rolling and feeding behaviour in cattle, which may require further investigation.

### **Contribution:**

This article was the first one to study whether tongue rolling in cattle has a de-arousal function, through examining heart rate before, during, and after tongue rolling. This made it an important selection for this review. Overall, this article provides evidence for the de-arousal coping function of tongue rolling against stressful conditions in cattle.

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Redbo, I. (1998). Relations between oral stereotypies, open-field behavior, and pituitary-adrenal system in growing dairy cattle. *Physiology & behavior*, 64(3), 273-278.

[https://doi.org/10.1016/S0031-9384\(98\)00059-6](https://doi.org/10.1016/S0031-9384(98)00059-6)

### **Summary:**

Previous literature has shown that tethering cattle results in increased urine cortisol levels. Also, it was found previously that releasing tied up cattle into open housing decreased tongue rolling despite unchanged feeding. These 2 ideas together support the idea that tethering is perceived as stressful/aversive by the cattle, and that confinement may be a possible stressor. However, not all cattle exhibit tongue rolling even under the same conditions, and the reason for this requires further research.

The objective of this article was to investigate the differences between calves that exhibit tongue rolling vs those that do not in response to a stressful situation and long-term tethering (being tied up). 48 Swedish calves (4-7 months old and 17-20 months old) were used as a sample population. All cattle were raised in open housing until they were transferred to a tied-up housing design (acted as a stressor). A scan sampling method was used to observe the cattle behaviour. Blood samples were also collected to determine cortisol and ACTH (stress indicating hormones) levels throughout the experiment.

This study determined that cattle who exhibit oral behaviours such as tongue rolling have a different response to stressors compared to non-tongue rolling cattle. The high stereotypic behaviour cattle had a lower cortisol response to stressors, and lower baseline levels of ACTH. This may provide further support that the tongue rolling behaviour is a mechanism by which cattle reduce stress.

### **Contribution:**

This article was one of the earliest to examine the endocrine system of cattle displaying tongue rolling behaviour. This article furthered research into the hormonal levels of tongue rolling cattle, and specifically how oral behaviours such as tongue rolling may impact hormonal response to stress (tethering). This article also introduces a potential reason for why tongue rolling behaviour may occur (to lower stress levels).

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Webb, L. E., van Reenen, C. G., Engel, B., Berends, H., Gerrits, W. J., & Bokkers, E. M. (2016). Understanding oral stereotypies in calves: Alternative strategies, hypothalamic–pituitary–adrenal axis (re)activity and gene by environment interactions. *animal*, 11(6), 1054-1062. <https://doi.org/10.1017/S1751731116002226>

### **Summary:**

Previous literature indicates that tongue rolling is a behavioural indicator of poor animal welfare and stress. Webb et al. 2016 point out that the link between stereotypies (repetitive, seemingly functionless behaviours) and cortisol (stress hormone) is unclear, as previous literature reports conflicting results.

This article focused on improving the knowledge around stereotypic behaviours and cortisol levels. The authors also focused their study on whether the display of tongue rolling in cattle relies on environmental influences altering gene expression.

This study was conducted in the Netherlands and used a video scan sampling method to observe tongue rolling behaviours in a total of 48 8-week-old cattle. In the first phase of the experiment, salivary cortisol was collected to compare between tongue rolling and non-tongue rolling cattle. The authors found that there was no significant relationship between the performance of tongue rolling and cortisol secretion in cattle. Stereotyping (tongue rolling) cattle and non-stereotyping cattle did not significantly differ in terms of cortisol secretion.

Once the cattle were 14-18 weeks old, they were split off randomly into different groups. The researchers manipulated the amount of solid food given to each group. This change in feed levels simulated an environmental stressor. Salivary cortisol was collected again. In this experiment, cortisol levels were associated with increased tongue rolling behaviour only under the lowest feed levels (known as the barren environment condition).

These results indicate that baseline cortisol levels are not associated with tongue rolling behaviour. However, environmental stressors (which increase cortisol levels), may mediate the development of tongue rolling. Overall, Webb et al. 2016 suggest that the environment (restricted diet) can impact cattle behaviour by altering gene expression and the production of cortisol.

### **Contribution:**

This article adds to the literature, to get a better idea of whether cortisol levels (indicators of stress) change with tongue rolling behaviour. With that being said, this study could benefit from studying blood levels along with levels in saliva. The amount of literature of tongue rolling behaviour at the hormonal/genetic level is low, so this study was chosen to get a better idea of these factors. Lastly, this study also makes the important claim that the environment impacts genetic components of the cattle, which results in the behaviour.

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Sato, S., Ueno, N., Seo, T., & Tokumoto, K. (1994). Haloperidol injections entirely suppress tongue-playing in cattle. *Journal of Ethology*, 12(1), 77-80. <https://doi.org/10.1007/BF02350084>

### **Summary:**

Sato et al. 1994 state that previous literature has determined that stereotypies such as tongue rolling are induced by amphetamine and mediated by dopamine. This gives an indication that environmentally induced stereotypies are related to the dopamine hormonal system in cattle. Previous research has been completed with mammals such as voles, monkeys, and pigs but not in cattle. To investigate the dopaminergic system, the researchers decided to inject the dopamine receptor inhibitor haloperidol into tongue rolling cattle to observe changes in behaviour. haloperidol is a drug that work to counteract the effects of dopamine. Scan sampling methods were used to observe each cattle.

The researchers used 4 Japanese cows (aged 13,13,9, and 5 years) that displayed tongue rolling, and 2 that did not (2 and 4 years old) for observation. The diets and housing conditions of the cattle were kept similar to limit confounding variables. Tongue rolling cattle were observed before injection (control 1), after haloperidol injection, and after injection with Ringer's solution (control 2). Ringer's solution simulates injection without changing hormone levels. Non-tongue rolling cattle were used as a control for normal behaviour (control 3).

It was determined that levels of tongue rolling were completely suppressed in cattle after haloperidol injection. The prevalence of tongue rolling behaviour after injection with Ringer's solution was not different from before injection or from the non-tongue rolling control. This shows that haloperidol can suppress tongue rolling behaviour. These results indicate that tongue rolling may appear when stressful conditions alter the dopamine system in cattle. More specifically, the researchers hypothesized that stress increases stereotypies such as tongue rolling by increasing sensitivity of the dopamine system.

### **Contribution:**

This article was chosen because it provides evidence of the underlying hormonal mechanisms behind tongue rolling behaviour. It gives greater insight on how tongue rolling behaviour manifests itself in cattle by studying hormones. Hormonal investigation is lacking for tongue rolling behaviour, so this article was chosen to get a better understanding.