1. **Introduction**

Monitoring of cattle behavior is of great importance to improve livestock management. Behavior is a term that is poorly understood. Therefore, monitoring animal behavior may enables us to predict future occasions by means of specific measured variables or elucidate responses to e.g. different social interactions, environmental conditions, reproductive state and diseases. These responses can be used to optimize the animal welfare and animal performance 1. For example, cattle develop a physiological negative energy balance (NEB) post partum due to the sudden increase amount of energy required for milk production and fetal growth whilst the increase of the capacity of the rumen can’t keep up with the amount of dry matter needed during the transition period.

Though, the rumen has not enough capacity to process that amount of dry matter to provide in the increased energy demand 2. Apparently, nutritional management, affecting social feeding behavior, in the transition period is of great importance to reduce the risk of health problems post partum associated with NEB 3. These health problems include (sub)clinical milk fever, metritis, ketosis or a retained placenta occurring mostly in the first two weeks of lactation 4. As a result of these diseases, economic losses may occur due to e.g. increased labor, veterinary costs, decreased milk yield and culling 5.These diseases could be identified earlier by monitoring transition eating behavior 3,5. In the transition period prepartum, increased sensitivity to health problems induces changes in the daily time budget of cattle. Cows with mild and severe forms of metritis spent less time eating and have a decreased dry matter intake, which already can be noticed 2 weeks prepartum, compared to healthy cows 6. Furthermore, González 5 described that ketosis was defined by a rapid decrease of dry matter intake 3 to 5 days prior to the day of detection. Changes in eating behavior may therefore be useful for early identification of herd problems and thus timely intervention in cattle herds to limit the economic losses. Although all cows experience difficulties facing the physiological changes during the transition period, it is important to account for behavior differences due to parity as well 7. For example, heifers, primiparous cows, show other feeding behavior in the transition period in comparison to multiparous cows. Primiparous cows spend more time eating in the prepartum period in comparison to multiparous cows. In the postpartum period, the opposite occurs. Multiparous cows spend more time eating per day in comparison to primiparous cows 7. Neave et al. also described the relation of lying behavior and parity in the transition period. Multiparous cows spend more time lying per day compared to primiparous cows 2 weeks before calving and 2 weeks after calving. Primiparous cows showed a greater number of lying bouts and a shorter lying bout duration in the transition period 7. As shown in the previous described study, the parity differences studied were focused on the transition period. However, limited data is available in relation to difference by stage of lactation, where this study will focus on.

Monitoring animal behavior has been done for a long time and various methods have been tested. Direct visual observation or analysis of video recordings are possible although labor intensive and time consuming 8,9. Additionally, the animal behavior may be influenced with subjective bias of the observer since the observer may influence the behavior of the animals being observed or the concentration of the observer varies throughout the day 9. Such drawbacks may be avoided by use of automatic behavior recording systems 8. Various automatic behavior recording systems have been described in the past few decades. For example, practically the first automatic system was a switch used as a pressure sensor to detect if the animal was standing/lying and a mercury filled sensor to detect walking in 1955 10. The pressure sensor was attached to the abdomen of the animal and the mercury filled sensor to the leg of the animal. Though, this sensor was prone to damage 10. *The following development in automatic behavior recording systems included the introduction of pedometers which contain a pendulum that moves in a switch causing the total steps to be counted* 10,11*. This method appeared to be inaccurate since the pedometer had to be individually calibrated* 11*. Another described method is the magnetic reed switch which contains a magnet that generates a magnetic field through motion, used in the late 80’s* 12*. This switch can be attached to the animal’s leg whereby a step will be detected when the magnet is separated from the switch. This sensor detected steps accurately, provided it was correctly positioned on the animal, which made it prone to errors* 10,12*. These methods are several examples of automatic behavior recording systems. Many of these systems only measure one or two behavior variables or activity states* 13. A sensor system measuring more than one behavior pattern at once provides a different solution. Taking account the previous described drawbacks, the system should be lightweight, small, shock resistant and easy to attach to an animal’s body 14. Accelerometers are sensors with high accuracy, developed over the last decades, meeting these requirements and used in the current study to measure various behavior variables including cattle leg activity, the time cattle spend ruminating, eating, lying and being inactive. With this information, algorithms are developed for automatic detection of cow behavior 15. An accelerometer is a sensor based on three-dimensional acceleration system, meaning it is able to detect acceleration on X (up and down), Y (left and right) and Z axes (forwards and backwards) 16,17.

The data measured by these accelerometers can only be used properly if we are aware of the normal limits of the data in relation to the stage of lactation in dairy cattle. To our knowledge, no report has been published to describe the normal range of such data in relation to all stages of lactation in dairy cattle, specifically taking account the age of the animal. Therefore, our study will determine these normal limits with accelerometer sensors and will outline this data against all stages of lactation *(days in milk)* and several parities. This may contribute to more knowledge about the normal ranges of cattle behavior which subsequently will support in early recognition of herd problems, perhaps before the sensitive transition period even starts.

Data measured by these accelerometers can only be used properly if we can define normal ranges of the behavior variables in relation to the stage of lactation in dairy cattle, also taking account of parity. To our knowledge, no report has been published to elucidate these ranges and thus defined normal behavior on the basis of these behavior variables. Therefore, this study will determine the effect of parity and stage of lactation on various behavioral variables including cattle leg activity and number of stand ups, the time cattle spend ruminating, eating and lying measured by accelerometer sensors. Elucidating this effect may contribute to more knowledge about behavioral ranges of cattle and subsequently support in early recognition of herd problems, perhaps before the sensitive transition period even starts.

**References**

1. González LA, Bishop-Hurley GJ, Handcock RN, Crossman C. Behavioral classification of data from collars containing motion sensors in grazing cattle. *Comput Electron Agric*. 2015;110:91-102. [https://www.scopus.com/inward/record.uri?eid=2-s2.0-84909594823&doi=10.1016%2fj.compag.2014.10.018&partnerID=40&md5=15e04aaea52dfd5e56e603f37ab2d9ef](https://www.scopus.com/inward/record.uri?eid=2-s2.0-84909594823&doi=10.1016%2fj.compag.2014.10.018&partnerID=40&md5=15e04aaea52dfd5e56e603f37ab2d9ef" \t "_blank). Accessed 8 November 2019. doi: 10.1016/j.compag.2014.10.018.

2. Hut PR, Mulder A, van den Broek J, et al. Sensor based eating time variables of dairy cows in the transition period related to the time to first service. *Prev Vet Med*. 2019;169. [https://www.scopus.com/inward/record.uri?eid=2-s2.0-85066253268&doi=10.1016%2fj.prevetmed.2019.104694&partnerID=40&md5=9e3e4622bd57df9d174e22a2378b2515](https://www.scopus.com/inward/record.uri?eid=2-s2.0-85066253268&doi=10.1016%2fj.prevetmed.2019.104694&partnerID=40&md5=9e3e4622bd57df9d174e22a2378b2515" \t "_blank). Accessed 8 November 2019. doi: 10.1016/j.prevetmed.2019.104694.

3. Goldhawk C, Chapinal N, Veira DM, Weary DM, Von Keyserlingk M. Prepartum feeding behavior is an early indicator of subclinical ketosis. *J Dairy Sci*. 2009;92(10):4971-4977.

4. Goff JP, Horst RL. Physiological changes at parturition and their relationship to metabolic disorders. *J Dairy Sci*. 1997;80(7):1260-1268.

5. González LA, Tolkamp BJ, Coffey MP, Ferret A, Kyriazakis I. Changes in feeding behavior as possible indicators for the automatic monitoring of health disorders in dairy cows. *J Dairy Sci*. 2008;91(3):1017-1028.

6. Huzzey JM, Veira DM, Weary DM, Von Keyserlingk M. Prepartum behavior and dry matter intake identify dairy cows at risk for metritis. *J Dairy Sci*. 2007;90(7):3220-3233.

7. Neave HW, Lomb J, von Keyserlingk, M. A. G., Behnam-Shabahang A, Weary DM. Parity differences in the behavior of transition dairy cows. *Journal of Dairy Science*. 2017;100(1):548-561. [http://www.sciencedirect.com/science/article/pii/S0022030216307718](http://www.sciencedirect.com/science/article/pii/S0022030216307718" \t "_blank). doi: [https://doi.org/10.3168/jds.2016-10987](https://doi.org/10.3168/jds.2016-10987" \t "_blank).

8. Müller R, Schrader L. A new method to measure behavioural activity levels in dairy cows. *Appl Anim Behav Sci*. 2003;83(4):247-258. [https://www.scopus.com/inward/record.uri?eid=2-s2.0-0141484320&doi=10.1016%2fS0168-1591%2803%2900141-2&partnerID=40&md5=c1d4fb24cf76da4471d15add3021df05](https://www.scopus.com/inward/record.uri?eid=2-s2.0-0141484320&doi=10.1016%2fS0168-1591%2803%2900141-2&partnerID=40&md5=c1d4fb24cf76da4471d15add3021df05" \t "_blank). Accessed 11 November 2019. doi: 10.1016/S0168-1591(03)00141-2.

9. Schwarz S, Hofmann MH, Gutzen C, Schlax S, Von Der Emde G. VIEWER: A program for visualising, recording, and analysing animal behaviour. *Comput Methods Programs Biomed*. 2002;67(1):55-66. [https://www.scopus.com/inward/record.uri?eid=2-s2.0-0036138108&doi=10.1016%2fS0169-2607%2800%2900150-4&partnerID=40&md5=f3fadfebab84a735efa6b4a2ee6b7599](https://www.scopus.com/inward/record.uri?eid=2-s2.0-0036138108&doi=10.1016%2fS0169-2607%2800%2900150-4&partnerID=40&md5=f3fadfebab84a735efa6b4a2ee6b7599" \t "_blank). Accessed 11 November 2019. doi: 10.1016/S0169-2607(00)00150-4.

10. Champion RA, Rutter SM, Penning PD. An automatic system to monitor lying, standing and walking behaviour of grazing animals. *Applied Animal Behaviour Science*. 1997;54(4):291-305. [http://www.sciencedirect.com/science/article/pii/S0168159196012105](http://www.sciencedirect.com/science/article/pii/S0168159196012105" \t "_blank). doi: [https://doi.org/10.1016/S0168-1591(96)01210-5](https://doi.org/10.1016/S0168-1591(96)01210-5" \t "_blank).

11. Powell TL. Pedometer measurements of the distance walked by grazing sheep in relation to weather. *Grass Forage Sci*. 1968;23(1):98-102.

12. Stuth JW, Searcy S. A new electronic approach to monitoring ingestive behavior of cattle. . 1987:236.

13. Martiskainen P, Järvinen M, Skön J, Tiirikainen J, Kolehmainen M, Mononen J. Cow behaviour pattern recognition using a three-dimensional accelerometer and support vector machines. *Applied Animal Behaviour Science*. 2009;119(1):32-38. [http://www.sciencedirect.com/science/article/pii/S0168159109000951](http://www.sciencedirect.com/science/article/pii/S0168159109000951" \t "_blank). doi: [https://doi.org/10.1016/j.applanim.2009.03.005](https://doi.org/10.1016/j.applanim.2009.03.005" \t "_blank).

14. Scheibe KM, Gromann C. Application testing of a new three-dimensional acceleration measuring system with wireless data transfer (WAS) for behavior analysis. *Behavior research methods*. 2006;38(3):427-433.

15. Trénel P, Jensen MB, Decker EL, Skjøth F. Technical note: Quantifying and characterizing behavior in dairy calves using the IceTag automatic recording device. *Journal of Dairy Science*. 2009;92(7):3397-3401. [http://www.sciencedirect.com/science/article/pii/S0022030209706575](http://www.sciencedirect.com/science/article/pii/S0022030209706575" \t "_blank). doi: [https://doi.org/10.3168/jds.2009-2040](https://doi.org/10.3168/jds.2009-2040" \t "_blank).

16. Santegoeds OJ. Predicting dairy cow parturition using real-time behavior data from accelerometers. .

17. Van Erp-Van der Kooij, E, Van de Brug M, Roelofs JB. Validation of nedap smarttag leg and neck to assess behavioural activity level in dairy cattle. *Proc.Precision Dairy Farming*. 2016:321-326.