Indian Journal of Animal Sciences **93** (7): 722–726, July 2023/Article
https://doi.org/10.56093/ijans.v93i7.127107

Incidence of hoof and leg injuries in dairy cow under different floor

DEEPAK UPADHYAY [1]✉, MUKESH SINGH[2], GYANEDRA KUMAR GAUR[2] and MED RAM VERMA[2]

ICAR-Indian Veterinary Research Institute, Bareilly, Uttar Pradesh 243 122 India

Received: 20 August 2022; Accepted: 8 June 2023

ABSTRACT

Present study explored the effect of different floor on hoof health and leg injuries of crossbred dairy cow. Animals (n=24), were randomly assigned into four groups with different floor combination in covered and open area, viz. T0 (concrete and brick paved), T1 (concrete and sand), T2 (rubber mat and sand) and T3 (rubber mat and brick paved). Hoof and limb lesion scores were recorded as per the standard protocol during study period. White line lesion score did not differ significantly, however, sole lesion score and inter-digital space lesion score differed significantly between the groups. Both, sole and interdigital space lesion scores were greater in T0 group. Total hoof lesion score was different between the groups with highest value in T0 group. Month wise hoof lesion scores differed significantly in 5th and 6th month between treatments. Decreasing trend was noticed in T1 and T2 from 5th month onwards. In contrast, T0 showed increase in hoof lesion score. Knee lesion score and hock lesion score were different between treatments. Higher scores were found in cows housed in T0 group, while lower scores were noted in T1 group. Knee lesion score decreased in T1 and T2 groups 4th month onwards, however no change was seen in T0 and T3 group. Similar trend was also seen for hock lesion score. In conclusion, provision of sand bed floor in open area of loose house with or without rubber mat floor in covered area was found superior for improving animal welfare in terms of lesser hoof and limb injuries.

Keywords: Hock lesions, Hoof health, Sand bed floor, White line lesion

Animal welfare's five freedom concept, globally recognized as gold standards in animal welfare, advocate that animal must be free from pain, injury and diseases (Mellor *et al.* 2020). Any prevailing physical injury in a herd suggests negative effect of the production environment (Aube *et al.* 2022). However, studies on prevalence of hoof lesion, from the European and North American herds, reports 40-70% of animals in herd are affected (e.g. Manske *et al.* 2002, Sogstad *et al.* 2005, Buch *et al.* 2011). Hock and knee lesions varying from mild hair loss to ulceration and swelling have also been reported (Jewell *et al.* 2019). Prevalence of hock injuries in dairy herd have been reported in the range of 42-73% (Weary and Taszkun 2000, von Keyserlingk *et al.* 2012, Zaffino Heyerhoff *et al.* 2014, Nash *et al.* 2016). These affections have serious economic and welfare consequences, not easy to cure, and reduce the longevity of dairy cows (Barberg *et al.* 2007). Thus, it is a matter of great concern for dairy herds. Floor of dairy house is a deciding factor for overall welfare of animal. Unfavourable flooring condition including hardness, poor hygiene, slipperiness, etc. predisposes animal to many problems including injury, lameness and mastitis. Hooves and legs are the most affected part of the animal body due to poor flooring, as they remain in direct contact. Unsuitable floor adversely affects hoof and leg health and comfort, predisposes animal to pain and ultimately affects productivity (Mishra *et al.* 2017). Hock and knee injuries are commonly described as being associated with a hard lying surface such as concrete (Huxley and Whay 2006, Weerashinghe *et al.* 2021). Instead of above facts, most of the dairy farms in India house their animals in hard concrete or brick floor. As concrete floor has been blamed to be detrimental to cow health, several options thus have been explored worldwide. Among them rubber mats and sand/straw bedding are most common. Deep-bedded sand floor have been reported to cause fewer hock injuries than mattresses (Nielsen *et al.* 2023). However, advantages as well as disadvantages for rubber mat have been reported with respect to hoof and leg injuries (Vockey *et al.* 2001, Boyle *et al.* 2005, Telezhenko *et al.* 2005). Keeping above facts in mind, an attempt has been made here to study the effect of different floor surface on hoof health and leg injuries of crossbred dairy cow.

MATERIALS AND METHODS

This study was conducted at ICAR–Indian Veterinary Research Institute (IVRI), Bareilly, Uttar Pradesh, India. Study area is located in humid-subtropical region at an altitude of 169.2 m above the mean sea level, at latitude of

Present address: [1]PAR Division, ICAR-Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh. [2]ICAR-Indian Veterinary Research Institute, Bareilly, Uttar Pradesh. ✉Corresponding author email: dpkvet@gmail.com

28°22' North and longitude of 79°24' East. Summer and monsoon season extend from early April to October, with an average annual rainfall of approximately 1714 mm and extreme temperature up to 44°C. Winter season commences in October, and minimum temperature up to 4°C reaches in January. The monthly mean temperature ranges from 14°C to 33°C. Crossbred cows (HF/Jersey/BS × Hariana, named as *Vrindavani*) (n=24), up to 3rd parity in their early lactation (<45 days in milk) were randomly assigned into four groups (6 in each). Loose housing system with covered (roofed) area over feeding platform and open resting area was provided. Roof was made up of corrugated cement sheets longitudinally oriented in East-West direction. Animals were milked in the milking parlor located at a distance of approximately 200 m from experimental shed. Concentrate ration was given as per milk yield at the time of milking. Green fodder (maize/berseem/oat) and dry fodder/ wheat straw were provided *ad lib*. Water troughs were provided in open area. Treatments in this experiment were, the different floor combinations in covered and open area of house, viz. T0 (concrete in covered, brick paved in open area), T1 (concrete in covered, sand bedded in open area), T2 (rubber mat in covered, sand bedded in open area), and T3 (rubber mat in covered, brick paved in open area). Animals were housed for 6 months (June-November) in these groups. Rubber mats (20 mm thick) used were made up of virgin rubber with channeled surface, and laid over the existing concrete floor. Sand bed (avg. 80 mm thick) was prepared using fine river sand over the existing brick paved floor of open area. Proper depth was maintained till the end of study by adding new sand, if required. Floor space was provided as per BIS (Bureau of Indian Standards) norms, i.e. more than 3.5 m^2 in covered area and 7 m^2 in open area for each cow.

The hooves of hind feet were examined after restraining animal in specially constructed restraining chute. Before scoring, hoofs were cleaned and lightly trimmed at weight bearing surface to localize the lesions. Recording for hoof lesions was done at 1st month of housing thereafter at interval of every 4 week. In this way, total 6 observations were made for each of 24 animals. Hoof lesions were classified as sole hemorrhages (blood-stained areas on the horn of the sole), white line disease (widening of the white line area), sole ulcers (a full thickness defect in the sole with dermis visible), heel horn erosion (erosion of the bulbs), interdigital dermatitis (superficial dermatitis located in the interdigital space) and digital dermatitis (superficial dermatitis located on the plantar aspect of the foot between the bulbs of the heels). An observer recorded for the presence and location of any hoof lesion and severity was then scored as per on-site method of Vockey *et al.* (2001) (Supplementary table 1). After examination of both feet, single score was given to each cow for each zone based on presence of lesion. For limb lesion, scoring knee (carpal) and hock (tarsal) joints of all four legs were examined. Limb lesion scoring was done on 1st day of housing and thereafter was repeated every 4 week period till the end of the study. During scoring, single observer observed for presence or absence of three attributes of injury, viz. hair loss, ulceration or wound and swelling on the joint. If the lesion was present in single leg it was scored while, when both legs were having lesions, the lesion with higher severity was considered. Severity score was assigned on 0-5 scale, as per Chaplin *et al.* (2000) which were further modified for this study (Supplementary Table 2).

The information collected by data sheet was pooled and analyzed as per standard statistical procedure (Snedecor and Cochran 1994). Kruskal-Wallis test was applied to test the significance difference between the groups.

RESULTS AND DISCUSSION

White line lesion score did not differ significantly, however, sole lesion score ($p<0.05$, $\chi2 = 15.17$) and inter-digital space lesion score ($p<0.05$, $\chi2 = 16.42$) differed significantly between the groups (Table 1). Both, sole and interdigital space lesion scores were greater in T0 group. Total hoof lesion scores (mean±SE) in T0, T1, T2 and T3 groups were 2.97±0.19, 1.78±0.18, 1.89±0.16 and 2.39±0.27, respectively. It was found that the total hoof lesion score was significantly different ($p<0.05$, $\chi2 = 20.37$) between the groups. Total hoof lesion score was also greater in cows housed in T0 group followed by T3, T2 and T1 groups.

Higher sole lesion score found in T0 and T3 group might have been due to constant strain on hoof by uneven surface of brick paved and concrete floor. This is also reflected as higher lameness score reported in these groups (Upadhyay *et al.* 2017). Harder surfaces (concrete and brick paved floor) result in more standing time (Upadhyay *et al.* 2021), which might also be the reason of higher hoof lesions scores in these groups. Sole bruising has already been linked with prolonged standing in several studies (Galindo and Broom 2000, Shearer *et al.* 2015, Eriksson *et al.* 2021). It may also be due to uneven wear and tear of hoof in brick paved floor as both growth and wear are affected by the abrasiveness of the flooring surfaces (Gregory *et al.* 2006). Instead of

Table 1. Lesion scores of various hoof zones (mean±SE) in cows housed under different floor

Groups	White line	Sole	Interdigital space	Total
T0 (CB)	0.56±0.13	0.89±0.10[a]	1.53±0.12[a]	2.97±0.19[a]
T1 (CS)	0.61±0.13	0.36±0.08[b]	0.81±0.14[b]	1.78±0.18[b]
T2 (RS)	0.44±0.12	0.47±0.09[b]	0.97±0.13[b]	1.89±0.16[b]
T3 (RB)	0.47±0.09	0.94±0.18[ab]	0.97±0.15[b]	2.39±0.27[ab]

Means bearing different superscripts a, b, c differ significantly ($p<0.05$) column wise.

Table 2. Total hoof lesion score (mean ±SE) in cows housed under different floor

Group	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Total
T0 (CB)	2.67±0.67	2.50±0.43	2.67±0.33	3.00±0.26	3.67±0.49^{a}	3.33±0.56^{a}	2.97±0.19^{a}
T1 (CS)	2.50±0.56	2.00±0.52	1.67±0.21	1.67±0.49	1.33±0.42^{b}	1.50±0.43^{ab}	1.78±0.18^{b}
T2 (RS)	2.83±0.40	2.33±0.21	2.17±0.17	1.50±0.43	1.33±0.21^{b}	1.17±0.48^{b}	1.89±0.16^{b}
T3 (RB)	2.50±0.76	2.33±0.56	2.17±0.79	2.50±0.85	2.17±0.83^{ab}	2.67±0.33^{ab}	2.39±0.27^{ab}

Means bearing different superscripts a, b, c differ significantly ($p<0.05$) column wise.

provision of rubber mat higher scores were recorded for T3 group. Boyle *et al.* (2005) also reported that rubber flooring had no effect on sole or white line lesion scores or on dermatitis scores. Rubber flooring has been discussed controversially because different studies found advantages as well as disadvantages regarding claw health (Fjeldass *et al.* 2011, Kremer *et al.* 2012). This might also be due to the fact that hoof horn growth and wear on the aged concrete did not differ from that on rubber mat (Telezhenko *et al.* 2005).

Monthly hoof lesion scores differed significantly ($p<0.05$) in 5th and 6th month between treatments (Table 2). Decreasing trend has been noticed in T1 and T2 from 5th month onwards. In contrast, T0 showed increase in hoof lesion score, while T3 showed more or less same total hoof score up to end of experiment. Thus it can be concluded that provision of sand resulted in improved hoof health. It might be due decreased claw loading owing to the sand properties like cushioning effect, equal weight distribution and more surface area of contact while standing unlike rubber or concrete. Confinement on concrete or other hard surfaces aggravates the physical effects of excessive load bearing on feet, whereas housing on earthen surfaces dampens these effects (Bicalho and Oikonomou 2013). Another reason might be the increased lying time (Upadhyay *et al.* 2021). As cow comfort play significant role in severity of claw lesion (Cook and Nordlund 2009). However, rubber mat could not be found promising with respect to hoof lesion score. Vockey *et al.* (2001) also concluded that there was no benefit of rubber alleys in preventing claw lesions.

On comparison of median changes (final-initial) in total hoof lesion score (Table 3) it was found that there was no change in total hoof lesion score in T0 and T3 groups, while it decreased in T1 and T2 groups. Number of animal that improved was highest in T2 group, while there was no animal in this group with worsened score. T0 group was having lower number of animals that improved during study period. Our findings are in agreement with Vockey *et al.* (2001) who reported that rubber-sand combination had higher number of animal with improved and lower number of animal with worsened hoof score. Boyle *et al.* (2005) suggested that even slight improvement in hoof health is of major importance considering that cows that develop lameness in their first lactation are more likely to become lame in subsequent lactations (Hirst *et al.* 2002).

Table 3. Median changes (final−initial) in total hoof lesion score in cows housed under different floor

Group	n	Median change in Total hoof score	Number of animal that		
			Improved	Did not change	Worsened
T0 (CB)	6	0	1	3	2
T1 (CS)	6	-0.5	3	2	1
T2 (RS)	6	-2	6	0	0
T3 (RB)	6	0	3	0	3

Knee lesion score ($p<0.05$, $\chi 2 = 12.93$) and hock lesion score ($p<0.05$, $\chi 2 = 8.65$) were found significantly different ($p<0.05$) between treatments (Tables 4 and 5). Both, knee lesion and hock lesion scores were found higher in cows housed in T0 group, while both the scores were lower in T1 group. Knee lesion score were decreased in T1 and T2 group from 4th month onwards, however no change was seen in T0 and T3 group with the time. Similar trend was also seen for hock lesion score. Lower knee and hock score in cow kept

Table 4. Knee lesion score (mean±SE) in cows housed under different floor

Group	Month 0	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Total
T0 (CB)	2.17±0.31	2.50±0.22	1.83±0.40	2.67±0.21^{ab}	2.33±0.21	2.00±0.00	2.67±0.21^{a}	2.31±0.10^{a}
T1 (CS)	1.33±0.42	1.67±0.61	1.50±0.43	1.67±0.33^{b}	2.00±0.26	1.83±0.31	1.83±0.31^{ab}	1.69±0.14^{b}
T2 (RS)	1.67±0.33	2.00±0.68	2.67±0.33	3.00±0.26a	2.50±0.22	1.83±0.31	1.50±0.34^{b}	2.17±0.16^{ab}
T3 (RB)	1.83±0.40	1.67±0.42	2.17±0.17	2.00±0.26^{ab}	1.83±0.17	2.33±0.21	2.17±0.17^{ab}	2.00±0.10^{ab}

Means bearing different superscripts a, b, c differ significantly ($p<0.05$) column wise.

Table 5. Hock lesion score (mean±SE) in cows housed under different floor

Group	Month 0	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Total
T0 (CB)	2.00±0.58	2.33±0.49	2.50±0.43	3.00±0.37^{ab}	2.50±0.43	2.00±0.37	2.50±0.50	2.40±0.17^{a}
T1 (CS)	2.67±0.49	1.33±0.56	1.50±0.22	1.67±0.33^{b}	2.00±0.26	1.67±0.21	2.33±0.56	1.88±0.16^{b}
T2 (RS)	2.33±0.33	2.00±0.52	1.83±0.31	2.33±0.33^{ab}	2.33±0.21	1.83±0.31	1.83±0.31	2.07±0.12^{ab}
T3 (RB)	1.83±0.31	2.00±0.52	2.50±0.22	3.00±0.00^{a}	2.17±0.31	2.33±0.21	2.50±0.22	2.33±0.12^{ab}

Means bearing different superscripts a, b, c differ significantly ($p<0.05$) column wise.

Table 6. Prevalence of leg injury lesion scores in cows housed under different floor

	T0 (CB)	T1 (CS)	T2 (RS)	T3 (RB)
Knee lesion score				
Max score of 1	0 (0%)	1 (16.67%)	0 (0%)	0 (0%)
Max score of 2	0 (0%)	3 (50%)	1 (16.67%)	3 (50%)
Max score of 3or 4	6 (100%)	2 (33.33%)	5 (83.33%)	3 (50%)
Hock lesion score				
Max score of 1	0 (0%)	1 (16.67%)	0 (0%)	0 (0%)
Max score of 2	0 (0%)	1 (16.67%)	1 (16.67%)	0 (0%)
Max score of 3or 4	6 (100%)	4 (66.67%)	5 (83.33%)	6 (100%)

Values in parenthesis indicate proportions.

over sand with concrete (T1) might be due to more lying in sand bedded area (Upadhyay *et al.* 2021) which offer more protective effect during lying and getting up. Our findings are in agreement with Vockey *et al.* (2001) who concluded that sand stalls alone were protective for hock lesions. Andreasen and Forkman (2012) reported that cows housed in facilities with deep-bedded sand stalls fewer integument alterations on the hocks (e.g. hairless patches, lesions, and swellings) and were less likely to be lame compared with cows housed in facilities with mattresses. Knee injuries were almost similar between T0 and T3 group. Thus in our study, rubber mat did not prove beneficial in reducing knee and hock lesion score. Our findings are in agreement with Wechsler *et al.* (2000) who concluded that rubber mat was less favourable for tarsal joints injuries than straw bedding. Cows kept in rubber mats showed more scabs or wounds in the knees (Buchwalder *et al.* 2000). Cows having knee lesion of maximum 3 or 4 (with serum or swelling) at least once were highest in T0 (Table 6). Similarly cow having hock lesion score of maximum 3 or 4 at least once were highest in T0 and T3. The presence of physical injury is an important indicator of negative effect of the environment (Aube *et al.* 2022). Problems with getting up and lying down owing to poor cubicle design and unsuitable lying surfaces can predispose to lesions to the hock, knees and teats (Munksgaard and Chaplin 2000). In this respect sand bedding in open area of loose house was found superior in our study.

In loose housing system, equipping open area with sand bed floor with either concrete or rubber mat in covered area improved animal welfare in terms of decreasing hoof and leg injuries. Rubber mat and brick combination was comparable to concrete and brick.

ACKNOWLEDGEMENTS

Authors are highly thankful to Director, IVRI for providing all the facilities to carry out this research work at Cattle and Buffalo farm. Financial assistance in the form of DST Inspire-Fellowship is gratefully acknowledged.

REFERENCES

Andreasen S N and Forkman B. 2012. The welfare of dairy cows is improved in relation to cleanliness and integument alterations on the hocks and lameness when sand is used as stall surface. *Journal of Dairy Science* **95**: 4961–67.

Aubé L, Mialon M M, Mollaret E, Mounier L, Veissier I A and de Boyer des Roches. 2022. Review: Assessment of dairy cow welfare at pasture: Measures available, gaps to address, and pathways to development of ad-hoc protocols. *Animal* **16**(8): 100597 https://doi.org/10.1016/j.animal.2022.100597.

Barberg A E, Endres M I, Salfer J A and Reneau J K. 2007. Performance and welfare of dairy cows in an alternative housing system in Minnesota. *Journal of Dairy Science* **90**:1575–83.

Bicalho R C and Oikonomou G. 2013. Control and prevention of lameness associated with claw lesions in dairy cows. *Livestock Science* **156**: 96–105.

Boyle L, Mee J, O'Donovan M and Kiernan P. 2005. Welfare and health of dairy cattle on outwintering pads or in cubicle housing with or without cushioned flooring. Project report. RMIS No. 5139 *Teagasc, Dairy Production Research Centre, Moorepark, Fermoy, Co. Cork* (www.teagasc.ie/research/reports/dairyproduction/5139/eopr-5139.asp.)

Buch L H, Sørensen A C, Lassen J, Berg P, Eriksson J Å, Jakobsen J H and Sørensen M K. 2011. Hygiene-related and feed related hoof diseases show different patterns of genetic correlations to clinical mastitis and female fertility. *Journal of Dairy Science* **94**: 1540–51.

Buchwalder T, Wechsler B, Hauser R, Schaub J and Friedli K. 2000. Liegeplatzqualität für Kühe im Boxenlaufstall im Test. *Agrarforschung* **7**: 292–96.

Chaplin S J, Tierney G, Stockwell C, Logue D N and Kelly M. 2000. An evaluation of mattresses and mats in two dairy units. *Applied Animal Behaviour Science* **66**: 263–72. https://doi.org/10.1016/S0168-1591(99)00100-8

Cook N B and Nordland K V. 2009. The influence of the environment on dairy cow behaviour, claw health and herd lameness dynamics. *Veterinary Journal* **179**: 360–69.

Eriksson H K, Daros R R, von Keyserlingk M A G and Weary D M. 2021. Standing behavior and sole horn lesions: A prospective observational longitudinal study. *Journal of Dairy Science* **104**(10): 11018–34. https://doi.org/10.3168/jds.2020-19839.

Fjeldaas T, Sogstad A M and Osteras O. 2011. Locomotion and claw disorders in Norwegian dairy cows housed in free stalls with slatted concrete, solid concrete, or solid rubber flooring in the alleys. *Journal of Dairy Sciences* **94**(3):1243–55.

Galindo F A and Broom D M. 2000. The relationships between social behaviour of dairy cows and the occurrence of lameness in three herds. *Research in Veterinary Science* **69**: 75–79.

Gregory N, Craggs L, Hobson N and Krogh C. 2006. Softening of cattle hoof soles and swelling of heel horn by environmental agents. *Food and Chemical Toxicology* **44**(8): 1223–27. https://doi.org/10.1016/j.fct.2006.01.018.

Hirst W M, Murray R D, Ward W R and French N P. 2002. A mixed-effects time to event analysis of the relationship between first lactation lameness and subsequent lameness in dairy cows in the UK. *Preventive Veterinary Medicine* **54**: 191–201.

Huxley J N and Whay H R. 2006. Current attitudes of cattle practitioners to pain and the use of analgesics in cattle.

Veterinary Record **159**: 662–68.

Jewell M T, Cameron M, Spears J, McKenna S L, Cockram M S, Sanchez J and Keefe G P. 2019. Prevalence of hock, knee, and neck skin lesions and associated risk factors in dairy herds in the Maritime Provinces of Canada. *Journal of Dairy Sciences* **102**(4): 3376–91.

Kremer P V, Scholz A M, Nüske S and Förster M. 2012. Do mats matter? – Comparison of fertility traits and milk yield in dairy cows on rubber or concrete flooring. *Archives Animal Breeding* **55**(5): 438–49.

Laven R and Livesey C. 2011. Getting to grips with hock lesion in cattle. *Veterinary Record* **169**: 632–33.

Manske T, Hultgren J and Bergsten C. 2002. Prevalence and interrelationships of hoof lesions and lameness in Swedish dairy cows. *Preventive Veterinary Medicine* **54**: 247–63.

Mellor D J, Beausoleil N J, Littlewood K E, McLean A N, McGreevy P D, Jones B and Wilkins C. 2020. The 2020 Five domains model: Including human–animal interactions in assessments of animal welfare. *Animals* **10**(10):1870. https://doi.org/10.3390/ani10101870.

Mishra M, Upadhyay D, Gurav A and Domple V. 2017. Effect of floor on lameness in crossbred dairy cow: A review. *International Journal of Livestock Research* **7**(12): 22–40. http://dx.doi.org/10.5455/ijlr.20170607061548

Munksgaard L and Chaplin S. 2000. Assessment of rising behaviour in tethered dairy cows as part of their welfare status. EAAP 2000, *Commission on Animal Management and Health, Paper* M2.9.

Nash C G R , Kelton D F, DeVries T J, Vasseur E, Coe J, Zaffino Heyerhoff J C, Bouffard V, Pellerin D, Rushen J, de Passillé A M and Haley D B. 2016. Prevalence of and risk factors for hock and knee injuries on dairy cows in tiestall housing in Canada. *Journal of Dairy Sciences* **99**(8): 6494–6506. https://doi.org/10.3168/jds.2015-10676

Nielsen S S, Alvarez J, Bicout D J, Calistri P, Canali E, Drewe J A, Garin-Bastuji B, Gonzales Rojas J L, Gortázar Schmidt C, Herskin M, Michel V, Miranda Chueca M Á, Padalino B, Roberts H C, Spoolder H, Stahl K, Velarde A, Viltrop A, De Boyer des Roches A, Jensen M B, Mee J, Green M, Thulke H H, Bailly-Caumette E, Candiani D, Lima E, Van der Stede Y and Winckler C. 2023. EFSA Panel on Animal Health and Animal Welfare (AHAW); Welfare of dairy cows. *EFSA Journal* **21**(5): e07993. doi: 10.2903/j.efsa.2023.7993.

Shearer J K, Plummer P J and Schleining J A. 2015. Perspectives on the treatment of claw lesions in cattle. *Veterinary Medicine (Auckland, N.Z.)* **6**: 273–92. doi: 10.2147/VMRR.S62071.

Snedecor G W and Cochran W G. 1994. *Statistical Methods*. Ninth Edition, Iowa State University Press.

Sogstad A M, Fjeldaas T, Osteras O and Forshell K P. 2005. Prevalence of claw lesions in Norwegian dairy cattle housed in tie stalls and free stalls. *Preventive Veterinary Medicine* **70**: 191–209.

Telezhenko E, Bergsten C, Magnusson M, Ventorp M, Hultgren J and Nilsson C. 2005. Effect of different flooring systems on the claw horn growth and wear in dairy cows. ISAH- Warsaw, Poland **1**: 320–23.

Upadhyay D, Singh M, Gaur G K, Bharti P K and Verma M R. 2021. Effect of flooring system on maintenance behaviours of cows. *Indian Journal of Animal Sciences* **91**(8): 675–80.

Upadhyay D, Singh M, Gaur G K, Patel B H M, Verma M R, Bharti P K and Dutt T. 2017. Does floor surface affect locomotion behaviour of crossbred cows under loose housing system? *Indian Journal of Animal Sciences* **87**(2): 159–62

Vockey F J, Guard C L, Erb H N and Galton D M. 2001. Effects of alley and stall surfaces on indices of claw and leg health in dairy cattle housed in a free-stall barn. *Journal of Dairy Sciences* **84**: 2686–99.

von Keyserlingk M A G, Barrientos A, Ito K, Galo E and Weary D M. 2012. Benchmarking cow comfort on North American free stall dairies: Lameness, leg injuries, lying time, facility design, and management for high-producing Holstein dairy cows. *Journal of Dairy Sciences* **95**: 7399–7408.

Weary D M and Taszkun I. 2000. Hock lesions and free-stall design. *Journal of Dairy Sciences* **83**: 697–702.

Wechsler B, Schaub J, Friedli K and Hauser R. 2000. Behaviour and leg injuries in dairy cows kept in cubicle systems with straw bedding or soft lying mats. *Applied Animal Behaviour Science* **69**:189–97. https://doi.org/10.1016/s0168-1591(00)00134-9

Weerasinghe W P C G, Rajapaksha E, Gunawardena W W D A, Ammunekumbura I D E M and Samarakone T S. 2021. Effect of rubber and concrete flooring on resting behavior, hock injuries, and milk production of primiparous Friesian crossbred dairy cows housed in a free-stall barn in Mid-Country, Sri Lanka. *Tropical Animal Health and Production* **53**(5): 447. doi: 10.1007/s11250-021-02885-y.

Zaffino Heyerhoff J C, LeBlanc S J, DeVries T J, Nash C G, Gibbons J, Orsel K, Barkema H W, Solano L, Rushen J, de Passillé A M and Haley D B. 2014. Prevalence of and factors associated with hock, knee, and neck injuries on dairy cows in freestall housing in Canada. *Journal of Dairy Sciences* **97**(1):173–84. doi: 10.3168/jds.2012-6367.