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REVIEWS

Drivers and indicators of dairy animal welfare in large-scale dairies (review)

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Abstract
While animal welfare concerns are rising globally, this has not been the case with lower- and middle-income economies in Africa and Asia such as Zimbabwe. These developing countries have their own problems which are not reported in developed countries, such as the harsh economic environment, limited technologies and different political and food security priorities. These factors limit focusing on animal welfare. Meanwhile, studies on animal welfare in these countries have been limited. The task of determining animal welfare is a very complex and can sometimes be very subjective since there is no gold standard protocol to be used in many developing countries. This paper reviews the main factors that are used to assess dairy animal welfare at a farm situation. The factors were categorised and generally discussed as drivers and indicators of dairy animal welfare. Key indicators reviewed in this study include but are not limited to production performance indicators, body condition scores, cleanliness scores, presence of clinical disease signs and physiological and behavioural indicators. Dairy animal welfare drivers discussed in this paper include but not limited to the general design of dairy cattle housing, presence of foot bath and shading facilities, presence and use of maternity paddocks, state of feeder and water troughs.

Keywords Drivers · Indicators · Dairy cattle · Animal welfare

Introduction

Animal welfare has received increasing concern from consumers of animal products particularly in the developed world, who are now demanding to know the particular environment and conditions in which animal products are produced, processed and marketed (Estévez-Moreno et al., 2021). In developing countries even though these animal welfare concerns are not as high as in developed countries, concerns on animal welfare are rising due to an increase in literacy rate and globalisation (Asebe et al., 2016). International organisations such as the World Organisation for Animal health (OIE), Farm Animal Welfare Committee(FAWC), World Animal Protection, International Animal Rescue, Blue Cross and International Fund for Animal Welfare have made numerous efforts to come up with policies and standards for improving animal welfare in all member states (Garcia, 2017). Nevertheless, implementation of these polices and standards in most developing countries such as Zimbabwe has not been very effective due to a rich heritage of cultural and religious traditions which has resulted in continued mistreatment of livestock. Zimbabwe is one of the many countries that have not yet developed comprehensive legislation governing animal welfare. The Prevention of Cruelty to Animals Act (Chapter 19:09), developed in 1964, has not been very effective in limiting cruelty to animals, and not much awareness has been done to raise public awareness of the act. Zimbabwe's livestock is classified into two main classes, i.e. commercial livestock producers and peasant livestock farmers. Commercial livestock farmers in Zimbabwe are a group of farmers who have really commercialised livestock production. These commercial livestock farmers take livestock farming as a business and produce livestock for sale, whereas with peasant livestock farmers, offtake is very low. The dairy sector in Zimbabwe is divided into large-scale dairy (milk 1000 L plus per day), medium-scale (500 L–1000 L/day), and small-holder dairy (less than 500 L/day). Management practices are also on the good and better side for large- and medium-scale dairy farmers when compared to small-holder dairy farmers. Studies in Zimbabwe with smallholder dairies have shown that dairy

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animal welfare is indeed compromised by the harsh climatic environment, high cost of conventional supplementation, unavailability and high cost of veterinary pharmaceuticals (Matore et al., 2018). It is therefore important that studies be conducted to look into various causes/drivers and indicators/signs of reduced dairy animal welfare. This paper critically reviews the animal and resource-based measurements that can be used to assess dairy animal welfare.

Animal welfare indicators

Animal/out-based measurements

Production performance

Production parameters can be used as good indicators of dairy animal welfare. These indicators include but not limited to fertility, growth rate, milk yield (Coignard et al., 2014) and life expectancy of the dairy cow. When using life expectancy as a measure of fertility, it can be said that the longer the life expectancy of a dairy cow, the better the welfare. However, the culling practice of the farmer should also be considered (Cockram, 2021). This is because some farmers may decide to keep high yielding cows for longer periods, but the cow may experience health problems such as chronic lameness (Archer et al., 2010a, b). When using milk yield as a measure of cow welfare, it is assumed that cows that produce a lot of milk are fed well and have access to ad libitum clean water supplies and those with lower yields are not properly fed. However, high production performance does not always imply good cow welfare, and low productivity does not also always imply poor welfare. Genetic selection for milk has often been accompanied by genetic deterioration in fertility, high disease incidence and negative energy balance that often lead to starvation (Oltenacu and Broom, 2010). There are instances where high yielding dairy cows are prone to mastitis, lameness and pendulous udder (Oltenacu & Broom, 2010). When selecting cows for milk production, it is preferable to select for optimum production rather than maximum production in order to maintain disease resistance ability and structural integrity of selected cows.

Body condition scores

Body condition scores on a scale of 1–5 (Table 1) can be used as production indicators of dairy cow welfare (Matthews et al., 2012). Low body condition score (1–2) of a dairy cow imply long-term discomfort that might be a result of hunger, a chronic infection or protein and energy under nutrition (Roche et al., 2009). In these scoring criteria, a cow with a condition of 3 is said to be in average body condition. On the other hand, high body condition scores indicate that the animal may be suffering from obesity. Nevertheless, descriptions of average body condition vary from producer to producer, with some farms using a scoring system of 1–9, where 1 represents very thin cows and 9 represents very fat cows. It is therefore important that producers calibrate the scoring system under their own conditions. The body condition of dairy cattle is determined by the quality and quantity of energy, proteins, minerals and vitamins it gets from its diet. The body condition of dairy cows needs to be kept in line with the physiological state, breed and age of the cow. Cows that a have low body condition have long postpartum anoestrus, and overweight cows in late gestation may experience birth complications and may suffer from metabolic disorders after parturition. Calf weight at parturition is also dependent on the dam's body condition. In general, good body condition scores depict good cow welfare while poor body condition scores depict long-term discomfort and hence poor welfare (Cook, 2018). Though body condition scores provide a reliable and easy measure of the amount of

Table 1 Body condition scoring criteria (Edmonson et al., 1989)

Condition	BCS	Description
Thin	1	Severely emaciated. All ribs and bones structure easily visible and physically weak.
	2	Emaciated, similar to 1 above but not weakened. Little visible muscle tissue.
	3	Very thin, no fat on ribs or brisket, and some muscle still visible. Back easily visible.
Borderline	4	Thin, with ribs easily visible but shoulders and hindquarters still showing fair muscling. Backbone visible.
Optimum	5	Moderate to thin. Last two or three ribs can be seen. Little evidence of fat on brisket over ribs or around tailhead.
	6	Good smooth appearance all throughout. Some fat deposition in brisket and over tailhead. Ribs covered and back appears rounded.
	7	Very good flesh, brisket full, tailhead shoes pockets of fat, and back appears square due to fat. Ribs very smooth.
Fat	8	Obese, back very square, brisket distended, heavy fat pockets around tailhead, and cow has square appearance due to excessive fat. Neck thin and short.
	9	Rarely seen. Very obese. Description of 8 taken to greater extremes. Heavy deposition of udder fat.

body reserves in an animal, enumerators of body condition scores need to be sufficiently trained.

Physiological indicators

Physiological responses to short-term problems in welfare can be used to identify behaviours that induce fear and distress in dairy cows such as whipping and shouting at cows. Fear and distress result in increased levels of cortisol, and negative acute phase proteins. The levels of these hormones in the blood can be used as welfare indicators (Robichaud et al., 2019). Cortisol levels can be also measured using less invasive methods such as faecal, urinary and salivary hormone assays. The main advantage with using stress hormone levels in blood as animal welfare indicators is the precision involved in assessing welfare; however, this method is expensive and requires more expertise than other methods. There is little doubt that changes in HPA activity and in other physiological systems have marked deleterious effects on the animal metabolism and immune system, and ultimately on their welfare. Thus, understanding the physiological responses to stress can play an important role on animal welfare. However, measures of these physiological changes provide only an unreliable indicator of the animal welfare. Thus, changes in plasma cortisol concentrations alone cannot be used to determine that the experience was aversive for the animal. In the case of prolonged or chronic stress, the situation is even less clear.

Lameness

Lameness has recently become the major health problem affecting the welfare of dairy cows (Moran, 2015). In the UK, it accounts for 10% of the culls that are done annually and herd lameness ranges from 10 to 50% (Archer et al., 2010a, b). Lameness is not a single disease but a symptom associated with a range of different conditions. Herd prevalence rates can vary hugely between farms because many factors can predispose clinical lameness and because of differences in stockmanship and farm environments, lameness brings with it several challenges to both the farmer and the cow. Some of the challenges are increases in veterinary costs, reduction in milk volumes, lowered fertility, pain and distress to the animal (Whay & Shearer, 2017). Causes of lameness vary from herd to herd; it can be caused by diseases such as foot rot, sole ulcers and digital dermatitis (Jewell et al., 2019b). Inadequate quality and quantity of nutrients which lower the body condition of animals can also cause foot disorders which results in lameness (Randall et al., 2018). Overgrown hooves can also impair animal movement resulting in lameness (Ring et al., 2018). Differences in abnormal structures such as fragile pasterns and splayed toes can also result in lame cows (Nguhiu-Mwangi et al., 2012). Leg and foot disorders are more common in confined dairy cows that spend a lot of time on concrete floors with little exercise. The amount of time an animal spends resting also determines its prevalence to lameness, as evidenced by studies done in North America whereby Holstein cows that spent 12.8-h resting had lower prevalence for lameness compared to those that spent only 11.2-h resting (Ito et al., 2010). It is important to note that lameness is not a single disease but a symptom associated with a range of different conditions. Herd prevalence rates can vary hugely between farms because many factors can predispose clinical lameness and because of differences in stockmanship and farm environments. To control lameness in grazing cows, there is a need to provide shade. However, at cow level, lameness has been negatively associated with milk yield. Herd lameness and individual lameness are therefore very important parameters that can be used to evaluate welfare of dairy animals.

Presence of clinical disease symptoms

Clinical diseases cause pain and discomfort to the cow, and ultimately impair welfare of the cow (Scott et al., 2003). However, the absence of disease and injury alone does not provide an accurate measure of animal welfare. Pre-pathological state of the animal indicates a weakened immune system and can also be a useful indicator of poor welfare (Etim et al., 2013). Somatic cell count in milk is also used to assess the pre-pathological condition of the cow (Sant'anna & Paranhos da Costa, 2011).

Mastitis is one of the most important diseases affecting herd productivity in dairy cows and is the disease that is responsible for most of the culls on dairy farms (Kielland et al., 2010). The presence of clinical mastitis signs results in impaired animal welfare due to the pain and changes in the animal's behaviour associated with mastitis. When using mastitis to assess animal welfare, there is need to consider the type of causative bacteria, the degree of infection as well as the number quarters affected and shedding the bacteria (De Vliegher et al., 2012). Other diseases used in assessing welfare of the dairy cow include bovine tuberculosis and skin conditions like the lumpy skin disease.

Ocular discharge, nasal discharge, coughing, laboured breathing and diarrhoea

Other clinical disease signs and conditions that can be used as indicators of dairy animal welfare include ocular discharge, nasal discharge, coughing, difficulties in breathing and diarrhoea (Ahsan et al., 2016). Nasal discharge refers to an excess of fluid material from the nasal cavity whose origin is either the gastrointestinal system or the respiratory system. Nasal discharge is usually a result of an accumulation of the normal respiratory discharge, but in some instances, it can be caused by an infection of the upper respiratory tract, and in this case, nasal discharge becomes an important welfare indicator (Crossley et al., 2022). Studies in Northern German with dairy farms have revealed that the percentage of cows with nasal discharge and ocular discharge increased with herd size (Gieseke et al., 2018). These results could be attributable to high disease transmission rate with increased population size, and in those situations, disease prevention measures have to be intensified. Ocular discharge from cattle is also a good indicator of compromised welfare. A survey from 93 farms in Ireland concluded that the proportion of cows that had ocular discharge was negatively associated with manual record health keeping and collecting yard area that was below the standard area of 1.4 m^2/cow (Crossley et al., 2022). It is therefore of paramount importance that space requirements per cow be adhered to in all cow housing environments. Other non-invasive measures of animal welfare include measurements of the respiratory rate, coughing, panting and laboured breathing (Love et al., 2014). Increased respiratory rate in dairy animals is an indicator of heat stress, and stress in dairy animals reduce milk production and fertility (Strutzke et al., 2018). It is therefore crucial that respiratory be monitored closely, and this will allow for early detection of heat stress and timely taking of counteractive measures.

Skin lesions

The presence or absence of lesions that are caused by environmental and management factors can be used as indicators for assessing cow welfare, and they indicate that the animal`s freedom from discomfort and freedom from diseases, pain and injury is being infringed (Jewell et al., 2019a). The presence of lesions that are not a result of past exposure to a disease on body parts such as the abdomen, neck and back of the animal indicates that the cow is living in a harmful environment and can be used for designing intervention strategies. Studies done in Kenya on the welfare of the dairy cow revealed that the presence of neck lesions was significantly associated with the absence of neck rails on feeding troughs (Aleri et al., 2012). Swellings, hairless patches and hock injuries are more common in housed dairy animals compared to animals with access to pasture.

Behavioural/ethological indicators

Ethological indicators refer to the behaviour a cow exhibits either under natural or ideal states (Nguhiu-Mwangi et al., 2013), and there are useful indicators of cow welfare. If an animal fails to behave normally or continues to behave abnormally for a long period, that is referred to as abnormal behaviour and it indicates compromised welfare. The main challenge when estimating animal behaviour is to understand what abnormal behaviour is, in order to assess it.

Social behaviour

Social behaviour of dairy cows is influenced by the nature of the production system as well as mixing and grouping of cattle (Gupta et al., 2008). There are two forms of social behaviour, i.e. combative behaviour characterised by fighting and pushing of one another as cows attempt to establish a social hierarchy and non-combative behaviour, which is exhibited by positive interactions such as sexual advancement. To advance animal welfare, housing and management should stimulate normal social development and allow cattle to adapt to their social environment through affiliative behaviour (Jensen, 2018). Under natural grazing conditions, dairy cattle are able to freely express ingestive behaviour such as selective grazing; therefore, cattle welfare under natural conditions is generally said to be better than the welfare of cattle under intensive zero grazing conditions (Charlton & Rutter, 2017). Pasture-grazed dairy cows feed selectively and have ample space to express normal social behaviour as opposed to housed cows that feed on what is offered to them and cannot freely express social behaviour (Dawkins, 2004).. High levels of aggressive interactions indicate that dairy cow welfare is under compromise as shy cows are often injured and bullied away from feed resources and resting areas (Fregonesi et al., 2007). Cows that are bullied away do not get the opportunity to eat freshly mixed feed and may suffer from diseases that are related to malnutrition which may compromise their welfare (Cardoso et al., 2019). Breed, physiological state, feeding space, resting and standing space (Schütz et al., 2010) among other factors influence frequency of aggressive interactions on dairy farms. Social behaviour attributes such as aggression can be estimated when determining welfare of dairy cows. When animals are mixed, aggressive behaviour is often the result as animals compete for food, water and resting space.

Behavioural deprivation

Animal welfare advocates and animal welfare scientist have always raised concerns on how different environments kept animals affect their ability to express normal behaviour and productivity in general (Tucker et al., 2021). Dairy animals like all domesticated animals have retained adaptations of their ancestors; therefore, they prefer an environment which allows them to express their normal behaviour (Bracke & Hopster, 2006). Any compromise in animal's natural environment will result in behavioural deprivation (Aubé et al., 2022). Behavioural deprivation is a key issue in animal welfare. Some housing facilities, for instance bans and shades, do not allow dairy animals to express normal behaviour towards their counterparts, and this may result in mental suffering of the animals in such environments. However, the biggest challenge in relating the relationship between behavioural deprivation and animal environment is not on determining which behavioural deprivation variable exists but is on determining how much of the changes in these variables results in suffering of dairy animals (Napolitano et al., 2012). Housed animal in free stall barns spend 600–700 min a day lying down. It is therefore important that dairy animals' resting hours for housed animals get observed. Three key measurements of resting behaviour that are related to animal welfare are duration of lying behaviour, percentage of collisions during down and percentage of cows lying completely or partly outside the resting area (Plesch et al., 2010).

Human-cow relationship

The human-cow relationship is a commonly used as a measure of animal welfare and is a function of (i) the stockperson's experience in the dairy industry; (ii) breed of the dairy cow, with the Jersey considered to be a docile breed, showing good relations with handlers; and (iii) environmental conditions such as a hot sunny or rainy day also affecting the way cows relate to handlers (Ivemeyer et al., 2018). For the human-cow relationship to be good, there is need for good stockmanship, which is demonstrated by the ability to identify sick, thirsty, and stressed cows and then take corrective action to arrest the welfare risk factors (Gabai & Novelli, 2018). Good human-animal relationship is shown by cows that do not express restless behaviour in the presence of the stockperson; positive interactions by the stockperson such as touching and talking to cows; and a stockperson who spends most of their time with dairy cows (Battini et al., 2011).

Avoidance distance test

Avoidance distance test is a measure of how close a person can approach a cow and is often used to assess the existence of a good human-to-animal relationship. Avoidance distance (also referred to as flight distance) is defined as how close a person can approach feeding animals or animals standing in collection yards (Windschnurer et al., 2008). When measuring avoidance distance, the stockperson moves towards a stationary cow from an angle of 90° at a shoulder angle (Windschnurer et al., 2009) up and until he touches the cow or the cow shows signs of withdrawal such as flicking of ears or stepping back. Distance between the cow and the last point where the stockperson will be standing before the cow shows withdrawal signs. Avoidance distance is categorized into cows that can be touched, cows that can be approached 50 cm but not touched, cows that can be approached as closely as 50–100 cm, and cows that cannot approached as closely as 100 cm (Forkman, 2009). Avoidance distance can be measured during feeding times to standardise the assessment and also to assess the animal`s motivation for feeding (Battini et al., 2016). A strained human-animal relationship is evident when animals move away from an approaching stockperson (Boivin et al., 2003). Dairy cows handled roughly learn to associate the handling with handlers (Munksgaard et al., 2001), and this learned fear of people has marked effects on productivity and welfare of the cow. Avoidance distance in dairy cattle is influenced by (i) frequency of contact with the stockperson, (ii) whipping and shouting of cows versus quiet and calm handling as well as the (iii) breed of the dairy cow (Grandin, 2010). For these needs to be realised, a farmer must be able to distinguish normal behaviour and abnormal behaviour, which requires considerable knowledge, experience and observation skills.

Input/resource-based measures of animal welfare

Shade

Shade is an important structure on dairy farms that protects cattle from extreme heat and direct sunshine (Schütz et al., 2010). When ambient temperature goes out of the comfort zone (18–25 °C), exotic dairy cows become heat stressed. Heat stress results in reduced feed intake, lowered milk production, embryonic death, poor oestrus expression and impaired growth rate (Polsky & von Keyserlingk, 2017). This will ultimately result in impaired cow welfare hence the relevance of shade in dairy cattle production. However, response to stress in dairy cows is dependent on breed. The comfort zone for exotic dairy breeds is 5–25 °C and when temperature exceeds 25 °C, production goes down whereas the comfort zone for Zebu cows ranges from 15 to 35 °C (Eberhardt et al., 2009). In designing shade structures for dairy cattle, if the floor is it to be in shade for a greater part of the day, an east–west orientation of the longitudinal axis is preferable as this type of orientation prevents direct sun heat (Kendall et al., 2006). However, if resources are limiting, particular shade can take a north–south orientation to keep the floor surface dry and this will help to control foot problems. Feed and water troughs can be under shade for a structure that has an east–west orientation which will allow dairy cows to drink cool water and eat fresh feed the whole day. For animals to lie and stand comfortably, shade must provide 2.5–3 m space per animal and a 3 m × 7 m roof can provide enough shade for eight cows (Schütz et al., 2010). For effective air circulation, the roof should have a height of 3 m. A smooth concrete floor must also be provided to allow cows to rest comfortably. Besides providing shade for troughs, shade reduces the time cows spend standing, thereby reducing lameness and consequently improving cow welfare (Das et al., 2016). Planting of trees and mounds of earth is also a good option for those dairy farmers that cannot afford to build shade structures. Mounds of earth can have drainage ditches between them to prevent damp conditions.

Footbaths

There is need for at least two footbaths at the entrance of the milking parlour. A footbath has to be 4.5 m long and 30 cm deep with concrete floors preferably with stones plucked into the concrete to prevent cows from slipping over (Cook et al., 2012). Cascade arrangement of the two baths is preferable for easy filling of fresh water. In a cascade arrangement, added fresh water overflows from one bath into the neighbouring bath and finally into an overflow outlet that connects to a collecting pit. Footbath water can be collected in settling tanks when water is scarce and reused later. Footbath water should be fresh and clean and must be mixed with a commercial disinfectant if its disease control functions are to be realized (Teixeira et al., 2010). The purpose of the foot bath is to wash mud and slurry off the feet of the cow. Mud and slurry may contain bacteria which can infect the cow, stockmen and consumers of dairy products. By controlling foot problems such as digital dermatitis and other infectious diseases, footbaths are important structures and have been reported to be associated with high locomotion scores on dairy farms (Cook et al., 2012). The association between high locomotion scores and the presence of footbaths on farms explains the welfare benefits of having foot baths on a farm.

Dairy cattle housing in large-scale dairy farms

Dairy cattle can be raised indoors or outdoors. Indoor housing is more common on large-scale dairy farms particularly in Europe where space for free range is not adequate, and if not well managed, a lot of welfare issues such as the inability of the cow to express normal behaviour can arise from this system (Popescu et al., 2014). The way housing and handling facilities are designed for dairy cows determines their freedom from discomfort hence their well-being (Kammel et al., 2019). Housing facilities are constructed (i) to give cows protection from extreme weather, (ii) for confining zero grazing dairy cows, and (iii) for effective control and monitoring of dairy cows. The majority of large-scale dairy farms in Zimbabwe provide overnight housing for dairy cows in order to monitor their health and control them. A good housing structure for dairy cows must ensure adequate lying and standing space per cow; allow the cow enough space to move around the pen freely without getting injured; allow the cow access to food (0.5 m/cow); and allow the cow to express its normal behaviour (Simensen et al., 2010). The way housing facilities for dairy cows are designed and managed influence cow cleanliness (des Roches et al., 2016), exposure to mastitis and lameness and thus welfare (Barker et al., 2010). This makes housing design an important risk factor when assessing cow welfare. Housing floors must be dry, clean and where applicable covered with deep clean dry bedding. Manure from cattle pens needs to be properly handled in order to minimise spread of disease and to reduce pollution of water sources. Solid manure needs to be stacked and used to fertilise field crops in summer while slurry needs to be collected inside a tank. Studies in Kenya revealed a significant association between the accumulation of slurry in housing facilities for dairy cows and the high number of dirty cows (Aleri et al., 2012). If manure and slurry are not regularly removed from cattle pens, cows are exposed to environmental mastitis and lameness (Fávero et al., 2015). Shade increases the time spent resting by cows and improves cow comfort and overall welfare of the dairy cow. Other studies have documented an association between lameness and milk yield, with locomotion scores being significantly higher in high yielding herds when compared to low or medium yielding dairy herds.

Conclusion

The concept of animal welfare has taken root in many developed countries when compared to developing countries such as Zimbabwe, Botswana and many other African countries. It is imperative that standardised parameters be set in place to determine indicators and drivers of dairy animal welfare in order to improve dairy productivity in low-income countries. A lot of studies on animal welfare have been conducted in developed countries and standardised protocols for assessing animal welfare developed in these countries. These parameters for assessing animal welfare are generally categorised as animal- and resource-based indicators of animal welfare, and they have been extensively discussed in this paper. Animal-based indicators of dairy animal welfare discussed in this chapter include the body condition score, lameness, and cleanliness; the presence of clinical disease signs; resting behaviour and avoidance distance. These animal-based indicators can be assessed at individual or group level. Resource-based measurements of animal welfare discussed in this chapter include the presence shade, design of animal housing and handling facilities, the presence of footbaths and quality of water in the foot bath as well as state of water and feed troughs. While most of the dairy animal welfare drivers and indicators from developed countries are applicable to developing countries, it is important that economic environment and cultural and religious beliefs of developing countries be considered as these greatly influence treatment and care of animals in these countries. From the study, it can be concluded that improvement in animal welfare results in improved animal health and productivity, hence the importance of understanding drivers and indicators of animal welfare.

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Declarations

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References

Ahsan, S., Islam, M. A., & Islam, M. T. (2016). On-farm welfare assessment of dairy cattle by animal-linked parameters in Bangladesh. *Research in Agriculture Livestock and Fisheries*, *3*(3), 417–424.

Aleri, J. W., Mogoa, E. M., & Mulei, C. M. (2012). Welfare of dairy cattle in the smallholder (zero-grazing) production systems in Nairobi and its environs. *Animal Welfare*, *24*(9), 1–7.

Archer, S. C., Bell, N., & Huxley, J. (2010). Lameness in UK dairy cows: a review of the current status. *In Practice*, *32*(10), 492–504.

Archer, S. C., Green, M. J., & Huxley, J. N. (2010). Association between milk yield and serial locomotion score assessments in UK dairy cows. *Journal of Dairy Science*, *93*(9), 4045–4053.

Asebe, G., Gelayenew, B., & Kumar, A. (2016). The general status of animal welfare in developing countries: the Case of Ethiopia. *Journal of Veterinary Science & Technology*, *7*(3).

Aubé, L., Mialon, M. M., Mollaret, E., Mounier, L., Veissier, I., & des Roches, A. de B. (2022). Assessment of dairy cow welfare at pasture: measures available, gaps to address, and pathways to development of ad-hoc protocols. *Animal*, *16*(8), 100597.

Barker, Z. E., Leach, K. A., Whay, H. R., Bell, N. J., & Main, D. C. J. (2010). Assessment of lameness prevalence and associated risk factors in dairy herds in England and Wales. *Journal of Dairy Science*, *93*(3), 932–941.

Battini, M., Andreoli, E., Barbieri, S., & Mattiello, S. (2011). Long-term stability of avoidance distance tests for on-farm assessment of dairy cow relationship to humans in alpine traditional husbandry systems. *Applied Animal Behaviour Science*, *135*(4), 267–270.

Battini, M., Barbieri, S., Waiblinger, S., & Mattiello, S. (2016). Validity and feasibility of human-animal relationship tests for on-farm welfare assessment in dairy goats. *Applied Animal Behaviour Science*, *178*, 32–39.

Boivin, X., Lensink, J., Tallet, C., & Veissier, I. (2003). Stockmanship and farm animal welfare. *Animal Welfare*, *12*(4), 479–492. http://www.ingentaconnect.com/content/ufaw/aw/2003/00000012/00000004/art00006

Bracke, M. B. M., & Hopster, H. (2006). Assessing the importance of natural behavior for animal welfare. *Journal of Agricultural and Environmental Ethics*, *19*(1), 77–89.

Cardoso, C. S., von Keyserlingk, M. G., & Hötzel, M. J. (2019). Views of dairy farmers, agricultural advisors, and lay citizens on the ideal dairy farm. *Journal of Dairy Science*, *102*(2), 1811–1821.

Charlton, G. L., & Rutter, S. M. (2017). The behaviour of housed dairy cattle with and without pasture access: a review. *Applied Animal Behaviour Science*, *192*, 2–9.

Cockram, M. S. (2021). Invited review: the welfare of cull dairy cows. *Applied Animal Science*, *37*(3), 334–352.

Coignard, M., Guatteo, R., Veissier, I., Lehébel, A., Hoogveld, C., Mounier, L., & Bareille, N. (2014). Does milk yield reflect the level of welfare in dairy herds? *The Veterinary Journal*, *199*(1), 184–187.

Cook, N. B., Rieman, J., Gomez, A., & Burgi, K. (2012). Observations on the design and use of footbaths for the control of infectious hoof disease in dairy cattle. *The Veterinary Journal*, *193*(3), 669–673.

Cook, N. B. (2018). Assessment of cattle welfare: common animal-based measures. In *Advances in Cattle Welfare* (pp. 27–53). Elsevier.

Crossley, R. E., Bokkers, E. A. M., Browne, N., Sugrue, K., Kennedy, E., Engel, B., & Conneely, M. (2022). Risk factors associated with the welfare of grazing dairy cows in spring-calving, hybrid pasture-based systems. *Preventive Veterinary Medicine*, *204*, 105640.

Das, R., Sailo, L., Verma, N., Bharti, P., & Saikia, J. (2016). Impact of heat stress on health and performance of dairy animals: a review. *Veterinary World*, *9*(3), 260.

Dawkins, M. S. (2004). Using behaviour to assess animal welfare. *Animal Welfare*, *13*(SUPPL.), 3–7.

De Vliegher, S., Fox, L. K., Piepers, S., McDougall, S., & Barkema, H. W. (2012). Invited review: mastitis in dairy heifers: nature of the disease, potential impact, prevention, and control. *Journal of Dairy Science*, *95*(3), 1025–1040.

des Roches, A. de B., Veissier, I., Boivin, X., Gilot-Fromont, E., & Mounier, L. (2016). A prospective exploration of farm, farmer, and animal characteristics in human-animal relationships: an epidemiological survey. *Journal of Dairy Science*, *99*(7), 5573–5585.

Eberhardt, B. G., Satrapa, R. A., Capinzaiki, C. R. L., Trinca, L. A., & Barros, C. M. (2009). Influence of the breed of bull (Bos taurus indicus vs. Bos taurus taurus) and the breed of cow (Bos taurus indicus, Bos taurus taurus and crossbred) on the resistance of bovine embryos to heat. *Animal Reproduction Science*, *114*(1), 54–61.

Edmonson, A. J., Lean, I. J., Weaver, L. D., Farver, T., & Webster, G. (1989). A body condition scoring chart for Holstein dairy cows. *Journal of Dairy Science*, *72*(1), 68–78.

Estévez-Moreno, L. X., María, G. A., Sepúlveda, W. S., Villarroel, M., & Miranda-de la Lama, G. C. (2021). Attitudes of meat consumers in Mexico and Spain about farm animal welfare: a cross-cultural study. *Meat Science*, *173*, 108377.

Etim, N. N., Offiong, E. E. A., Eyoh, G. D., Udo, M. D., Campus, O. A., & Ibom, A. (2013). *Stress and animal welfare: an uneasy relationship*. *1*(1), 9–16.

Fávero, S., Portilho, F. V. R., Oliveira, A. C. R., Langoni, H., & Pantoja, J. C. F. (2015). Factors associated with mastitis epidemiologic indexes, animal hygiene, and bulk milk bacterial concentrations in dairy herds housed on compost bedding. *Livestock Science*, *181*, 220–230.

Forkman, B. (2009). *Assessment of animal welfare measures for dairy cattle, beef bulls and veal calves*. Univ., School of City and Regional Planning.

Fregonesi, J. A., Tucker, C. B., & Weary, D. M. (2007). Overstocking reduces lying time in dairy cows. *Journal of Dairy Science*, *90*(7), 3349–3354.

Gabai, G., & Novelli, E. (2018). Investigating the troublesome relationship between the cow milk and human health. *Research in Veterinary Science*, *120*, 1–3.

Garcia, R. (2017). One Welfare': a framework to support the implementation of OIE animal welfare standards. *Bull. OIE*, *2017*, 3–8.

Gieseke, D., Lambertz, C., & Gauly, M. (2018). Relationship between herd size and measures of animal welfare on dairy cattle farms with freestall housing in Germany. *Journal of Dairy Science*, *101*(8), 7397–7411.

Grandin, T. (2010). How to improve livestock handling and reduce stress. *Improving Animal Welfare: A Practical Approach*, 64–87.

Gupta, S., Earley, B., Nolan, M., Formentin, E., & Crowe, M. A. (2008). Effect of repeated regrouping and relocation on behaviour of steers. *Applied Animal Behaviour Science*, *110*(3), 229–243.

Ito, K., Von Keyserlingk, M. A. G., LeBlanc, S. J., & Weary, D. M. (2010). Lying behavior as an indicator of lameness in dairy cows. *Journal of Dairy Science*, *93*(8), 3553–3560.

Ivemeyer, S., Simantke, C., Ebinghaus, A., Poulsen, P. H., Sorensen, J. T., Rousing, T., Palme, R., & Knierim, U. (2018). Herd-level associations between human–animal relationship, management, fecal cortisol metabolites, and udder health of organic dairy cows. *Journal of Dairy Science*, *101*(8), 7361–7374.

Jensen, M. B. (2018). The role of social behavior in cattle welfare. In *Advances in Cattle Welfare* (pp. 123–155). Elsevier.

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

Jewell, M. T., Cameron, M., Spears, J., McKenna, S. L., Cockram, M. S., Sanchez, J., & Keefe, G. P. (2019b). Prevalence of lameness and associated risk factors on dairy farms in the Maritime Provinces of Canada [Epub ahead of print]. *Journal of Dairy Science*.

Kammel, D. W., Burgi, K., & Lewis, J. (2019). Design and management of proper handling systems for dairy cows. *Veterinary Clinics: Food Animal Practice*, *35*(1), 195–227.

Kendall, P. E., Nielsen, P. P., Webster, J. R., Verkerk, G. A., Littlejohn, R. P., & Matthews, L. R. (2006). The effects of providing shade to lactating dairy cows in a temperate climate. *Livestock Science*, *103*(1), 148–157.

Kielland, C., Skjerve, E., Østerås, O., & Zanella, A. J. (2010). Dairy farmer attitudes and empathy toward animals are associated with animal welfare indicators. *Journal of Dairy Science*, *93*(7), 2998–3006.

Love, W. J., Lehenbauer, T. W., Kass, P. H., Van Eenennaam, A. L., & Aly, S. S. (2014). Development of a novel clinical scoring system for on-farm diagnosis of bovine respiratory disease in pre-weaned dairy calves. *PeerJ*, *2*, e238.

Matore, Z., Woods, P., & Kagler, S. (2018). Risk factors and indicators of reduced welfare of grazing dairy cows from selected smallholder dairy farms in Midlands Province, Zimbabwe. *Tropical Animal Health and Production*, 1–6. https://doi.org/10.1007/s11250-018-1530-x

Matthews, L. R., Cameron, C., Sheahan, A. J., Kolver, E. S., & Roche, J. R. (2012). Associations among dairy cow body condition and welfare-associated behavioral traits. *Journal of Dairy Science*, *95*(5), 2595–2601.

Moran, J. B. (2015). *Developing a farm audit to address the problems of stock welfare on small holder dairy farms in Asia*. *6*(February), 26–34. https://doi.org/https://doi.org/10.5897/IJLP2014.0235

Munksgaard, L., DePassille, A. M., Rushen, J., Herskin, M. S., & Kristensen, A.-M. (2001). Dairy cows' fear of people: social learning, milk yield and behaviour at milking. *Applied Animal Behaviour Science*, *73*(1), 15–26.

Napolitano, F., De Rosa, G., Grasso, F., & Wemelsfelder, F. (2012). Qualitative behaviour assessment of dairy buffaloes (Bubalus bubalis). *Applied Animal Behaviour Science*, *141*(3–4), 91–100.

Nguhiu-Mwangi, J., Mogoa, E. G. M., Aleri, J. W., & Mbithi, P. M. F. (2013). *Indicators of poor welfare in dairy cows within smallholder zero-grazing units in the peri-urban areas of Nairobi, Kenya*. INTECH Open Access Publisher.

Nguhiu-Mwangi, J., Wabacha, J. K., Mbuthia, P. G., & Mbithi, P. M. F. (2012). *Risk (predisposing) factors for non-infectious claw disorders in dairy cows under varying zero-grazing systems*. INTECH Open Access Publisher.

Oltenacu, P. a., & Broom, D. M. (2010). The impact of genetic selection for increased milk yield on the welfare of dairy cows. *Animal Welfare*, *19*(SUPPL. 1), 39–49.

Oltenacu, P. A., & Broom, D. M. (2010). The impact of genetic selection for increased milk yield on the welfare of dairy cows. *Animal Welfare*, *19*(1), 39–49.

Plesch, G., Broerkens, N., Laister, S., Winckler, C., & Knierim, U. (2010). Reliability and feasibility of selected measures concerning resting behaviour for the on-farm welfare assessment in dairy cows. *Applied Animal Behaviour Science*, *126*(1–2), 19–26.

Polsky, L., & von Keyserlingk, M. A. G. (2017). Invited review: effects of heat stress on dairy cattle welfare. *Journal of Dairy Science*, *100*(11), 8645–8657.

Popescu, S., Borda, C., Diugan, E. A., Niculae, M., Stefan, R., & Sandru, C. D. (2014). The effect of the housing system on the welfare quality of dairy cows. *Italian Journal of Animal Science*, *13*(1), 2940.

Randall, L. V, Green, M. J., Green, L. E., Chagunda, M. G. G., Mason, C., Archer, S. C., & Huxley, J. N. (2018). The contribution of previous lameness events and body condition score to the occurrence of lameness in dairy herds: a study of 2 herds. *Journal of Dairy Science*, *101*(2), 1311–1324.

Ring, S. C., Twomey, A. J., Byrne, N., Kelleher, M. M., Pabiou, T., Doherty, M. L., & Berry, D. P. (2018). Genetic selection for hoof health traits and cow mobility scores can accelerate the rate of genetic gain in producer-scored lameness in dairy cows. *Journal of Dairy Science*, *101*(11), 10034–10047.

Robichaud, M. V., Rushen, J., de Passillé, A. M., Vasseur, E., Haley, D., & Pellerin, D. (2019). Associations between on-farm cow welfare indicators and productivity and profitability on Canadian dairies: II. On tiestall farms. *Journal of Dairy Science*.

Roche, J. R., Friggens, N. C., Kay, J. K., Fisher, M. W., Stafford, K. J., & Berry, D. P. (2009). Invited review: body condition score and its association with dairy cow productivity, health, and welfare. *Journal of Dairy Science*, *92*(12), 5769–5801. https://doi.org/10.3168/jds.2009-2431

Sant'anna, a C., & Paranhos da Costa, M. J. R. (2011). The relationship between dairy cow hygiene and somatic cell count in milk. *Journal of Dairy Science*, *94*(8), 3835–3844. https://doi.org/10.3168/jds.2010-3951

Schütz, K. E., Rogers, A. R., Poulouin, Y. A., Cox, N. R., & Tucker, C. B. (2010). The amount of shade influences the behavior and physiology of dairy cattle. *Journal of Dairy Science*, *93*(1), 125–133.

Scott, E. M., Fitzpatrick, J. L., Nolan, A. M., Reid, J., & Wiseman, M. L. (2003). Evaluation of welfare state based on interpretation of multiple indices. *ANIMAL WELFARE-POTTERS BAR THEN WHEATHAMPSTEAD-*, *12*(4), 457–468.

Simensen, E., Østerås, O., Bøe, K. E., Kielland, C., Ruud, L. E., & Næss, G. (2010). Housing system and herd size interactions in Norwegian dairy herds; associations with performance and disease incidence. *Acta Veterinaria Scandinavica*, *52*(1), 1.

Strutzke, S., Fiske, D., Hoffmann, G., Ammon, C., Heuwieser, W., & Amon, T. (2018). Technical note: development of a noninvasive respiration rate sensor for cattle Journal of Dairy Science. 102 (1), 690–695. *Online:* https://doi.org/10.3168/Jds*, 14999*.

Teixeira, A. G. V, Machado, V. S., Caixeta, L. S., Pereira, R. V, & Bicalho, R. C. (2010). Efficacy of formalin, copper sulfate, and a commercial footbath product in the control of digital dermatitis. *Journal of Dairy Science*, *93*(8), 3628–3634.

Tucker, C. B., Jensen, M. B., de Passillé, A. M., Hänninen, L., & Rushen, J. (2021). Invited review: lying time and the welfare of dairy cows. *Journal of Dairy Science*, *104*(1), 20–46.

Whay, H. R., & Shearer, J. K. (2017). The impact of lameness on welfare of the dairy cow. *Veterinary Clinics: Food Animal Practice*, *33*(2), 153–164.

Windschnurer, I., Boivin, X., & Waiblinger, S. (2009). Reliability of an avoidance distance test for the assessment of animals' responsiveness to humans and a preliminary investigation of its association with farmers' attitudes on bull fattening farms. *Applied Animal Behaviour Science*, *117*(3), 117–127.

Windschnurer, I., Schmied, C., Boivin, X., & Waiblinger, S. (2008). Reliability and inter-test relationship of tests for on-farm assessment of dairy cows' relationship to humans. *Applied Animal Behaviour Science*, *114*(1–2), 37–53.