Investigating Dairy Cattle Welfare in Iran

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Abstract

Dairy cattle welfare has implications not only for the economic performance of individual farms but also for public perception of the dairy sector, both of which are critical to the long-term sustainability of the industry. Although intensive dairy farming practices were introduced in Iran in the 1940s, there remains a paucity of data concerning the welfare status of dairy cattle in the country. In response to this gap, the present study aimed to develop and implement a comprehensive welfare assessment protocol for use on intensive Iranian dairy farms, with the objective of generating baseline data to inform future welfare improvements and identify risk factors associated with tail damage, lameness, and injuries of the tarsus and carpus (hock and knee). The welfare assessment protocol was developed based on a comprehensive review of existing literature and the research team's understanding of welfare issues on Iranian farms and comprised 11 animal-based, 16 resource-based and management-based, and 2 stockmanship-related assessments, as well as 10 categories of farm records. This protocol was implemented across 62 intensive dairy farms located in five arid/semi-arid provinces of Iran. Sample size recommendations from the Welfare Quality protocol were applied to determine the minimum number of animals required for each animal-based measure, apart from locomotion scoring and tail damage scoring at parlour exit. For these measures, either the entire milking herd was assessed or all cows within the early lactation group (i.e., ≤150 days in milk) were included. Results showed a discrepancy regarding nutrition management on the farms with body condition score being well-managed (average of 0.5% lean and 0.2% obese cows) but an evident lack of feed and water trough space on 17 and 9 farms, respectively (n=62). Prevalence of lameness was 33% and higher than the global average of 21%, while hock and knee injuries were comparable to the high end of studies on housed dairy cattle (e.g., 41% cows with hock swelling). Prevalence of broken tails was the highest in the world and there was a significant lack of understanding of the scale of the problem within the farmers with median farmer estimation of broken tails being 2.0%. Hoof trimming was considered a routine procedure with 51/56 farms trimming the hooves ≥2 times a year, and it had the largest effect on both lameness and broken tails. Higher frequency of hoof trimming was associated with decreased lameness (e.g., OR 0.55 when trimming >2 times versus <2 times a year) but increased broken tails on the farms (OR 4.87 when trimming >2 times versus <2 times a year). Injuries of hock and knee were associated with a range of risk factors, with only farming system being shared between all lesions. This variation in the type of risk factors associated with the lesions indicates that their aetiologies may be distinct. Our findings highlight significant disparities in cow welfare between farms and demonstrate the need to move from broad assessments to a more in-depth welfare assessment on Iranian farms.

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In-preps

Jafari-Gh, A., Laven, R., Khaloubagheri, F., Mirrahimi, M.H., Jafari-Gh., S., Banadaky, M.D., Mueller, K.R. and Vallee, E. An Investigation of Dairy Cattle Welfare in Commercial Iranian Farms: Results from Resource-Based Measures and Management Practices- *in-prep*.

Jafari-Gh, A., Laven, R., Khaloubagheri, F., Mirrahimi, M.H., Jafari-Gh., S., Banadaky, M.D., Mueller, K.R. and Vallee, E. Risk Factors Associated with lameness and injuries of tarsus and carpus joints in Iranian intensive dairy cattle farms- *in-prep*.

Jafari-Gh, A., Laven, R., Khaloubagheri, F., Mirrahimi, M.H., Jafari-Gh., S., Banadaky, M.D., Mueller, K.R. and Vallee, E. Risk Factors Associated with tail damage on Iranian intensive dairy cattle farms and a comparison of two tail scoring methods- *in-prep*.

Conferences

Jafari-Gh, A., Laven, R., Khaloubagheri, F., Jafari-Gh., S., Mirrahimi, S.M.H., Dehghan-Banadaki, M., Muller, K. and Vallee, E., 2025. Investigating dairy cattle welfare on intensive farms: feed and water availability. *American Dairy Science Association annual meeting*, Louisville, Kentucky, USA

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General Introduction

The domestication and integration of cattle into Iranian agriculture can be traced back to at least the early to mid-sixth millennium BCE [1]. This long-standing history has given rise to a substantial body of traditional knowledge and practices associated with cattle husbandry. In terms of animal welfare, these practices emphasize respectful treatment of livestock and generally avoid interventions such as tail docking and tethering [2,3]. However, the onset of industrialisation in Iran during the 1930s paved the way for the adoption of intensive dairy farming practices in the early 1940s [4], modelled on the US system. Ironically, the tensions between the Islamic Republic and the USA have contributed to the devastation of Iran's economy in the last few decades. The perishing economy combined with the socio-political unrests have negatively influenced the farmers' ability to move beyond anything more than the survival mode. This will eventually have negative impacts on the quality of the life of the cattle living on these farms. For example, the social unrests in the last decade have led to several nationwide uprisings, which have been brutally suppressed (e.g., the massacre of the January 2026). Farmers have suffered a lot from these unrests and the following suppressions, and as a result, the number of farmers who were willing to participate in this study declined hugely after the death of Mahsa Jina Amini in September 2022 (explained in chapter 2). The dying economy is also a major issue for

Iranian dairy industry, which is mainly an intensive system and depends on imported feedstuff to feed the cattle.

Given that intensive farming relies heavily on the consumption of high amounts of grains and the use of preserved forages, the field of animal nutrition emerged as one of the earliest specialised disciplines within the Iranian Animal Science Research Institute, which began in 1960s [5]. Reflecting the growing importance of this field, the University of Tehran introduced a doctoral program in Animal Nutrition in the early 1990s, marking it as the first PhD course offered in the domain of animal sciences followed by doctoral programs in Genetics and Breeding and Animal Physiology [6]. Despite the extensive inclusion of nutrition-related subjects within both undergraduate and postgraduate curricula in Animal Science, the topic of "Animal Welfare" has not been formally integrated into academic programs at any level in Iran. As such, dairy cattle welfare has not yet been systematically assessed in the country. This gap persists despite the government's strategic emphasis on expanding dairy product exports [4] and emerging evidence from recent studies indicating that Iranian consumers increasingly value high standards of dairy cattle welfare and are willing to pay a premium for products that meet these expectations [7]. Thus, we aimed to develop a comprehensive welfare assessment protocol to encompass animal-based, resource-based, and stockperson-related indicators, in addition to farm records. This protocol was designed to facilitate the systematic evaluation of welfare conditions on intensive dairy farms in Iran and to generate baseline data on the welfare status of dairy cattle within the country. Additionally, risk factor analyses were done for tail breakage, lameness, and injuries of hock and knee.

Chapter 1

Review of Literature

1.1 Animal Welfare and Farm Productivity

Animal welfare, in its simplest and most sensible way, is defined as "being healthy" and having "what it wants" (from an animal perspective; [8]). For more than 40 years, it was believed that the profits gained from animal welfare are "intangible" [9]. However, recent research shows that welfare can have enormous financial impacts on livestock farming both through consumer preferences and operational efficiency [8,10]. Evidence indicates that the welfare status of animals, particularly the interactions between livestock and stockpersons, can significantly affect productivity [11] and thus influencing the efficiency of farming which is of outmost importance to feed the growing human population [12]. Enhancing animal welfare can improve farm efficiency not only by increasing productivity, but also through various additional mechanisms, including reduced mortality rates, improved animal health and well-being, and a lower incidence of zoonotic diseases and animal-borne infections [3,8]. It is important to acknowledge that not all improvements in animal welfare yield immediate gains in efficiency or financial returns. Thus, external drivers, such as public concern and societal expectations, play a critical role in advancing welfare standards within livestock production systems.

1.2 Animal Welfare and The Public

A key factor prompting increased attention to animal welfare among farmers and other stakeholders in the livestock industry is growing public concern regarding the conditions under which animals are raised and produce food. Empirical research from Australia indicates a decline in public trust toward the livestock sector in recent years, underscoring the importance of aligning industry practices with societal expectations [13]. The public holds a wide range of concerns regarding cattle farming, including issues related water scarcity, declining biodiversity, methane emission and climate change, and animal welfare. There is evidence that animal welfare plays a pivotal role in maintaining public trust and farmers' social license to operate [10]. The concept of social license to operate has recently been developed and happens when the community (whether it be local or international) implicitly approves the activities of a certain enterprise or industry [10]. It has been suggested that failure to maintain social license to operate can not only increase litigations and obligatory regulations [14,15], but also increase public demand and decrease public trust, which will decelerate or even stop the industry's growth [14,16]. For instance, a recent report by the Red Meat Advisory Council of Australia estimates that the cumulative economic losses associated with failing to maintain the livestock industry's social license to operate could reach up to USD 3 billion by 2030 [17]. These threats to social license can be mitigated through engagement with the community, including efforts to understand their needs and demands, and to address concerns regarding such important issues as animal welfare [18].

No matter how important animal welfare is for regaining and maintaining the public trust and social license, farmers will eventually have to consider the trade-off between costs and benefits of implementing welfare programs. These benefits are usually obscure until the prevalence and severity of the welfare-related problems is known, and a financial estimate can be made based on that. Once these financial gains are known to the farmer, it is less likely that animal welfare is seen in the opposite side of efficient farming [19], and it is more likely to be seen as a priority by the industry and in regions where animal welfare dose not receive the attention it deserves [8].

The importance of assessing cattle welfare in Iran is of paramount importance given the limited availability of data on this aspect of dairy farming. Despite reports suggesting that traditional animal husbandry practices in Iran emphasize respectful treatment of livestock, reflecting cultural values that regard animal rearing as an honourable activity [2], systematic evaluations of welfare conditions remain scarce in the academic literature. All available literatures on farm animals in Iran that explicitly reference "animal welfare" either in the title or in the key words have been published after 2020 and remain limited to a small number of studies [3,7,20,21]. Nonetheless, different welfare parameters such as lameness [22], mastitis [23,24] and reproduction performance [25] of dairy cattle have been extensively studied in Iran. In contrast, the situation in New Zealand is reversed, with a strong emphasis placed on comprehensive welfare assessments.

1.3 Evolution of Animal Welfare

Although public concern for animal welfare has only recently gained prominence within academic discourse, the origins of this concern date back several decades. Public attention was first drawn to the conditions of animals in intensive farming systems with the publication of “Animal Machines” by Ruth Harrison in 1964 [26]. This seminal work significantly raised awareness about the ethical treatment of animals and contributed to the recognition of their right to live free from mental and physical distress and eventually led to the creation of the “Five Freedom” concept in 1965 [27]. This concept has been the basis for most welfare protocols and is used as a benchmark for meeting animals’ needs. Building on this framework, Professor David Mellor of Massey University adopted the Five Freedoms in 1994 to develop welfare guidelines for animals used in research, teaching, and testing, which later informed the development of his influential "Five Domains Model", which now encompasses the welfare of farm animals as well as zoo animals, wildlife, and companion animals [28]. Since the creation of these models, many researchers or regulatory bodies have proposed diverse definitions and interpretations for animal welfare. These interpretations range from simple definitions such as those proposed by Webster [29]: "good welfare is fit and feeling good", and by Dawkins [8]: "are the animals healthy? Do they have what they want?" to more complex and thorough descriptions as that proposed by Farm Animal Welfare Council [27]: "welfare principally concerns both physical and mental health, which is largely determined by the skills of the stockman, the system of husbandry and the suitability of the genotype for the environment". However, the evolution of the human's understanding of animal welfare is not limited to the simplicity or complexity of the definitions created for animal welfare; it was more about the way we realised the physiological and mental states of the animals (Figure 1.1). This evolution led to the creation of different approaches to animal welfare, and such concepts as the Five Freedoms [30], the Five Domains [28], the life worth living and good life concepts (representing the quality of life) [27], and the Pillars of Animal Welfare [31] were introduced as a result.

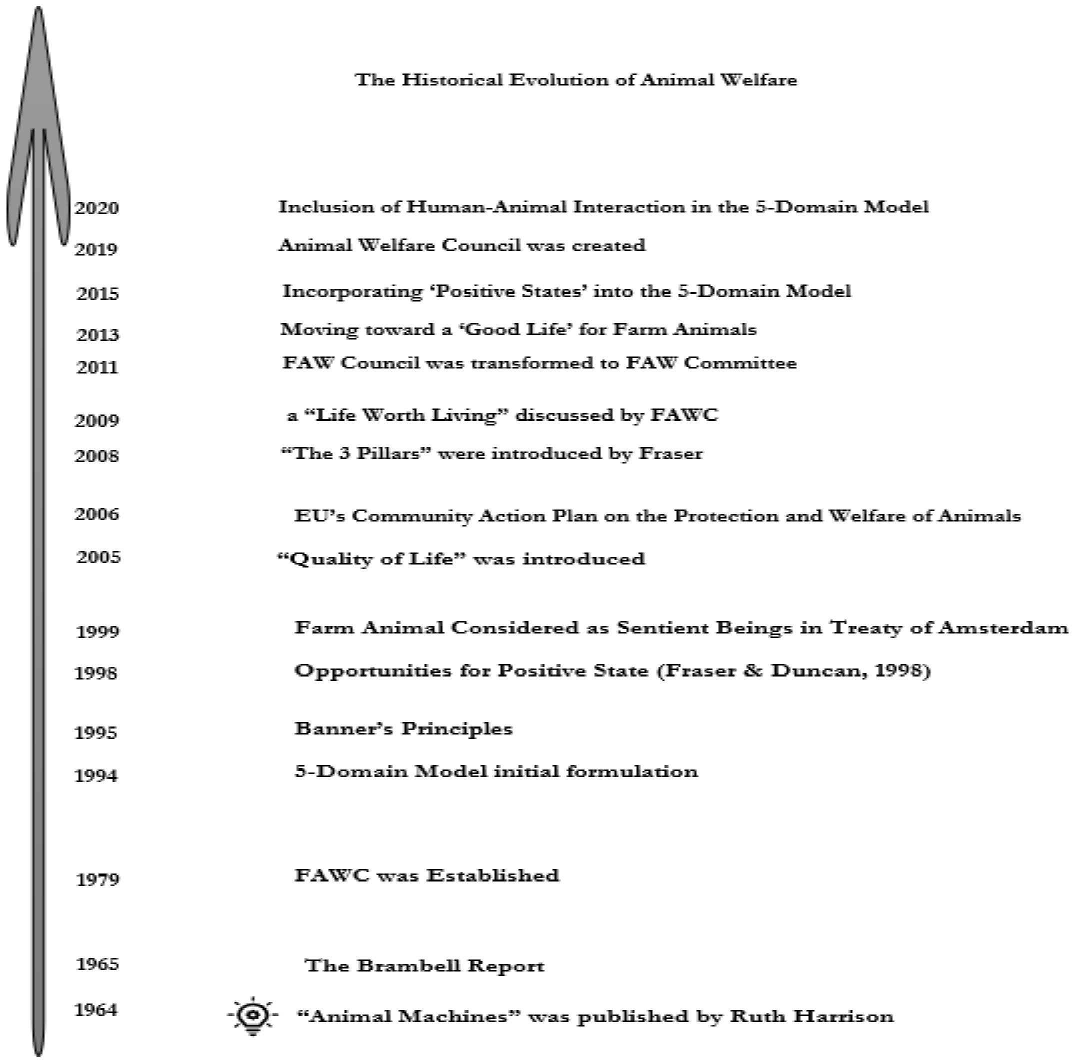

Figure 1.1. The history of animal welfare

1.4 Practical Use of Welfare Protocols

The European Commission adopted a Community Action Plan on the Protection and Welfare of Animals in early 2006 aiming to propose a clearer definition of animal welfare, keep developing high standards, present a better way to utilise resources, find replacements for animal testing, and finally make sure policies set by EU on animal welfare are coherent and coordinated [32]. This initiative was grounded in the recognition of animals as "sentient beings whose specific needs must be taken into account, and also that the protection of animals is an expression of humanity in the 21st century and a challenge facing European civilisation and culture" [32]. The Commission concluded that fostering greater public awareness and engagement is essential for advancing animal welfare. Therefore, the commission suggested that methods be developed to measure the welfare of animals, producers in other countries be able to voluntarily access the certification system, and animal welfare labelling be done on farm-animal related food products.

Several public and private organisations have developed practical tools and programs for assessing animal welfare on dairy farms. These initiatives aim to monitor welfare conditions throughout the animal's lifespan and support the application of welfare-based labelling on animal-derived food products, with scoring systems that reflect the level of welfare achieved during its lifespan (Figure 1.2).

Step 1 No crates, no cages, no crowding	Step 2 Enriched environment	Step 3 Enhanced outdoor access	Step 4 Pasture centered	Step 5 Animal centered; all physical alterations prohibited	Step 5+ Animal centered; entire life on same farm
Like people, animals need a little "personal space" to be comfortable.	It's the simple things that keep animals active and engaged — like a bale of straw for chickens to hide behind and climb on, a bowling ball for pigs to manipulate and shove around, or a few sturdy objects for cattle to rub against when they need a good scratch.	Pigs and chickens still live in buildings but they all — yes, each and every one of them — have access to outdoor areas where they can catch a few rays.	Chickens need to forage, pigs need to wallow and cattle need to roam. They can do all of these things when they live outdoors and have shelter — and of course, a view!	Animals get to live their lives with all the parts they were born with, and nothing else! No nose rings, no clipping, no snipping and no branding.	Animals are born and live their entire lives on one farm. Pigs and cattle are slaughtered on the farm, and chickens are transported only short distances (because you can't herd chickens!).

Figure 1.2. Left: "Animal Welfare Approved" label given by AGW organization; Right: Different animal welfare scores given to animal-based products in Canada and Europe markets.

Examples of these organisations include Royal Society for Prevention of Cruelty against Animals (RSPCA), UK Soil Association, and Assured Food Standards in the United Kingdoms, A Greener World (AGW), Humane Farm Animal Care, and National Milk producers Federation in the United States, and Dairy Farmers of Canada (DFC) in Canada. These organisations have contributed to increasing the welfare of cattle across various production systems (*i.e.*, tie-stall, free-stall, and pasture-based systems) by developing such programs as FARM, AssureWel, Red Tractor, and ProAction.

Additionally, there has been a vast body of literature with comprehensive welfare assessments on dairy cattle farms across different countries (e.g., [33-35]). These studies use a range of animal-based, resource-based, and stockperson-based measures to assess the welfare of dairy cows on commercial farms. This study adopts a similar approach.

We hypothesize that animal welfare is currently underprioritized on Iranian dairy farms, primarily due to the absence of legal mandates requiring farmers to adopt welfare standards and the ongoing challenges related to feed shortages within the industry. Therefore, this study aims to assess the welfare status of dairy cattle in Iran, with the objective of illuminating the prevalence and severity of welfare-related issues. The findings will serve as a baseline for evaluating the trade-offs between the costs and benefits of implementing welfare programs in the country.

The next two chapters explain how a welfare assessment protocol was designed to evaluate the welfare of dairy cattle on Iranian intensive dairy cattle farms. Chapters two and three will provide a description of overall welfare on the farms, and chapters four and five will demonstrate the risk factors associated with lameness and injuries of tarsus and carpus, and tail breakage.

Foreword to the ***following*** chapters:

Chapter two has been published in a peer-reviewed scientific journal, and chapters three to five have been prepared for publication. This might result in some overlap in the introductory sections to ensure that each chapter can stand alone as an independent publication. Furthermore, minor formatting revisions have been applied to the second chapter after publication to ensure uniformity across chapters. These changes are strictly typographical and do not alter the scientific content or conclusions of the original paper.

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STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Ali Jafari Ghavamabad
Name and title of main supervisor:	Professor Richard Laven
In which chapter is the manuscript/published work?	2

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

Ali: Conceptualisation, Methodology, Protocol Development, Investigation and Data Curation, Formal Analysis, Writing, Funding Acquisition
Richard: Conceptualisation, Methodology, Protocol Development, Formal Analysis, Writing (editing), Funding Acquisition, Project Administration, Supervision
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Chapter 2

An Investigation of Dairy Cattle Welfare in Commercial Iranian Farms: Results from Animal- and Stockperson-Based Measures

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Jafari-Gh, A., 2024. Tail damage in dairy cows: a forgotten welfare issue, *The 2nd International Dairy Cow Conference*, Sari, Iran

Jafari-Gh, A., 2024. Welfare of dairy cows before milking. *The 7th National Conference on Livestock Management*, Kerman, Iran

2.1 Abstract

Dairy cow welfare can impact both the economic performance of an individual farm and the public perception of the sector thus influencing the sustainability of the dairy farming industry. Intensive dairy farming in Iran started in the 1940s, but there are limited data available regarding dairy cattle welfare in the country. Therefore, the aim of this study was to design and use a comprehensive bespoke welfare assessment protocol in intensive Iranian dairy farms to provide baseline data for Iran and other countries with similar farming systems. The protocol consists of animal-based, stockperson-based, and resource-based measures. The first part of the welfare assessment protocol (being presented in this paper) was developed from the existing literature and contained 11 animal-based and 2 stockmanship measures. The protocol was applied in 62 intensive dairy cattle farms in five arid and semi-arid provinces of Iran. Welfare Quality sample size suggestions were used to reach the minimum sample size for all animal-based measures except for loco-motion score where either the whole milking herd was scored or all cows in the early lactation (<150 days in milk) group. Results show that there was a good focus on nutrition management on the farms. Lameness prevalence and the incidence of hock lesions were too high although within the range seen in many housed cows outside Iran. In addition, 13.5% of cows had damaged ears. Prevalence of dirty legs was high (≥80% of cows) and hygiene score was unrelated to farming system. Finally, the extremely high median

prevalence of tail damage (60%) indicates a significant welfare issue that needs to be addressed with urgency.

2. 2 Introduction

Dairy cattle welfare is crucial to the sustainability of the dairy farming industry as it can influence both the economic performance of an individual farm [16] and the public perception of the sector [10,13,21,36]. Indeed, animal welfare is of paramount importance to sustain the social license of dairy farming as consumers and other stakeholders expect dairy cattle to have, at least, a life worth living [10,13].

Independent welfare assessment is used as a means of demonstrating that on-farm welfare is meeting or exceeding standards by using animal-based, resource-based, and stockperson-based measures to assess, either directly or indirectly, the welfare of the animal [37]. Therefore, farm assurance schemes (e.g., AssureWel, and Red Tractor) are now widely used in many, though far from all, countries [35,38-40].

Domestic cattle have been a significant part of Iranian agriculture since at least the early-to-mid sixth millennium BCE [1]. As such there is a considerable amount of 'traditional practice' related to cattle rearing in Iran. In relation to animal welfare, this practice is focused on treating animals with respect and avoiding practices such as tail docking or tethering [2,3]. On the other hand, intensive dairy farming (i.e., a system in which animals are kept in confined environment, consume high amount of grains and are fed principally on preserved forages rather than grazed grass) has been present for a much shorter period of time (~80 years) [4]. To date, there have been no systematic assessments of animal welfare in this non-traditional farming industry, even though the Iranian government is focused on increasing the export of dairy products [4], and recent research has shown that Iranian consumers are demanding and willing to pay for high dairy cattle welfare standards [7].

Therefore, the aim of this study was to develop a comprehensive welfare assessment protocol that included animal-based, resource-based, and stockperson-based measures, alongside farm records, on intensive Iranian dairy farms and to use this protocol to systematically assess welfare on Iranian dairy farms and produce baseline welfare data for dairy cattle in Iran. This paper presents the development of that protocol and a descriptive report of the outcomes of the assessment of animal- and stockperson-based welfare measures.

2. 3 Material and Methods

The Animal Ethics Committee of the College of Agricultural and Natural Re-sources, University of Tehran approved all procedures used in this research.

2. 3. 1 Development of the Welfare Assessment Protocol

Since intensive dairy farming in Iran is very close to the North American system, multiple papers published in that region plus some European and NZ studies were used as baseline data for the development of the protocol (see Appendix A for list of papers). In addition, other European welfare protocols such as the Welfare Quality [41] and AssureWel [42] assessments were consulted. Measures that could potentially be assessed on intensive Iranian dairy farms were listed by the research team, who then created a shortlist of the measures that they thought would be essential to assess. This shortlist was then used to create an assessment tool which was tested and finalised, alongside calibration of the assessors using the University of Tehran dairy cattle farm (Karaj, Iran). Additional assessments could be added to the protocol during the visits if the research team identified an area of interest that was not covered by the protocol. Thus, not all the assessments were undertaken on all 62 farms.

2. 3. 2 Testing and finalisation of welfare assessment protocol, and calibration of assessors

Testing of the feasibility and practicability of the assessment process took three months (February to April 2022). It was undertaken alongside the calibration of the research team (i.e. comparing scores and discussing differences). Where thought necessary (locomotion scoring and tail scoring) the scoring process was filmed, and the film and the individual scores recorded by the team members were sent to R.L (a re-searcher who has significant experience in the scoring systems being used). He provided commentary on the scoring to ensure that the research team reached a common understanding about the scoring systems (e.g., how a locomotion score 2 cow moves different parts of her body, or how different types of tail injury present). The dataset from this process was not included in any analysis; however, the university farm was formally assessed later.

2. 3. 3 Study Population

The aim was to visit at least 60 intensive dairy farms [33] from five key dairying provinces in Iran: Tehran, Isfahan, Alborz, Qom, and Khorasan. A convenience selection was made with snowball sampling used to increase the probability of a selected farmer agreeing to be included [43]. Before any data collection, it was explained to the farmer that any data gathered would be anonymised and only published in an aggregated report. Verbal consent was obtained before the assessment started.

2. 3. 3 Sample Size

The whole lactating herd was initially chosen as the target population. For locomotion scoring only, all lactating cows were scored, and for other assessments the recommendations by Cook [44] were used to identify a sample size that would identify the true prevalence with 95% confidence to a precision of 5% (assuming true prevalence of 50%). After five farm visits it was concluded that this sample size was too large, limiting the number of farms that could be assessed within the timeframe available, and limiting the value of the study as a model for future welfare audits. Thus, target population was changed from all lactating cows to cows in early lactation (days in milk [DIM] <150). The exception to this was on farms where cows were not grouped based on DIM. Again, for locomotion score, the whole target population was scored, and for other assessments sample size was calculated in order to identify true prevalence with 95% confidence to a precision of 15% (expected true prevalence of 50%; [41]).

2. 3. 4 Farm Visits

Farm visits started in May 2022 and finished in March 2023. The aim was to visit each farm only once, and for data gathering to take one working day. The visits started by asking a set of questions about the farm such as total number of animals, the number of the lactating herd, their management routines, and by asking the farmer to show the research team different sections of the farm e.g. calving area, milking shed, and group pens. Relevant comments made by the farmer during the process were recorded informally before the farm assessment.

2. 3. 5 Data Gathering Process

The data gathering and handling team consisted of four members: A.J-Gh. (animal scientist), F.K (farmer, agronomist), S.J-Gh. (animal scientist), M.H.M (senior veterinary medicine student). A.J-Gh. was the sole person responsible for locomotion scoring, body condition scoring, hock lesions, and tail scoring. Other measures were scored by the other team members based on their availability and workload.

2. 3. 6 Animal-based Measures

Measures were divided into different groups based on the part of the farm where the assessment was done (see Figure 2.1). For the measures assessed in pens, scoring was undertaken around feeding time when most cows were standing. Only cows standing in the feed alley (free stall farms; FS) or the walking area (bedded-pack farms; BP) were sampled. Cows that were lying down were excluded to minimise disturbance. If the number of eligible cows exceeded the sample size needed (i.e. N), animals were sampled systematically. For free stall farms with a feed alley, the alley was mentally divided into three sections and N/3 cows were sampled in each of those sections. For bedded-pack farms, the walking area was divided into four sections and N/4 cows sampled per section. For each section, the assessment started with the animal closest to start of that section, and every other animal was scored until N/3 or N/4 animals had been scored (or next whole number). For these in-pen assessments, cows that were clearly nervous when approached (i.e. large flight zone) were excluded from assessment.

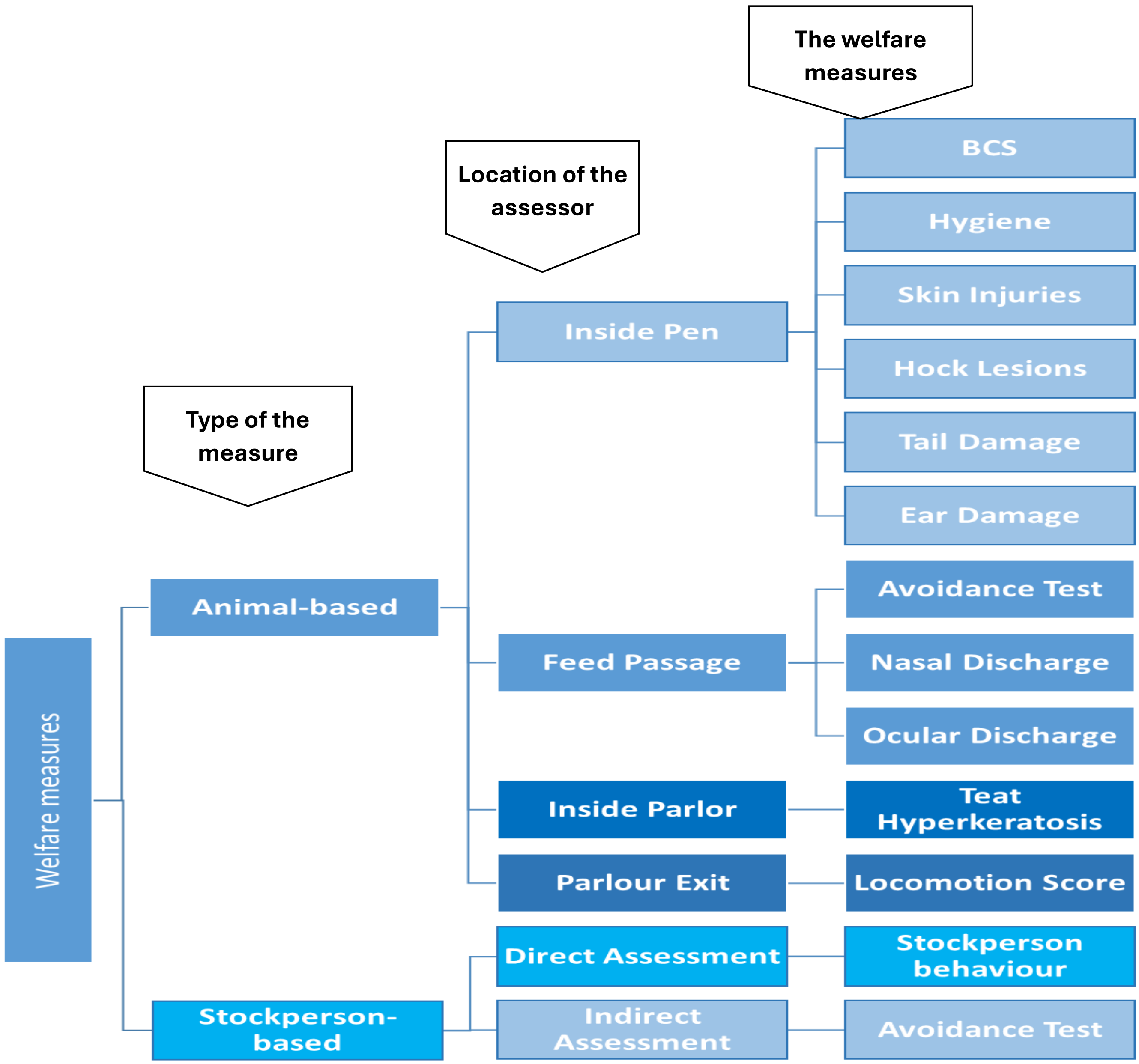

Figure 2.1. Animal-based and stockperson-based measures assessed and the location of the assessments

2. 3. 7 Scoring Systems

2. 3. 7. 1 Measures assessed with the assessor in the pen

These were BCS, body hygiene, tail damage, skin lesions, ear damage (the latter was assessed from 5th farm onward only), and hock health (from 8th farm onward only). BCS was scored visually using the 1 to 5 UK system [45] with a score <2 identifying a cow that was too lean and a score >4 a cow that was too obese.

Body hygiene was scored separately in lower leg, upper leg, udder, and tail using a three-point (0 to 2) system [46]. A cow was considered too dirty if the score was 2 (i.e., ≥25% of the area was dirty). Both sides of the body were observed and scored (0-3) for skin injuries as per Cook [44], with score ≥2 indicating significant damage. Ear damage was recorded based on visible signs of any tears in the ears as a presence/absence (Figure 2.2).

Figure2.2. Examples of cows with ripped ears. This was considered as ear damage in this study.

Hock (dorsal joints) lesions were assessed by separately recording signs of hair loss, ulceration, and swelling on a 4-point scale [47]. Any score of ≥2 was recorded as significant hock damage.

Tail damage was visually assessed using a modified version of New Zealand Veterinary Association tail scoring system [48]. Briefly, the tail was divided into thirds (three equal zones) from its top (zone 1) to the bottom (zone 3). Three forms of tail damage were recorded: trauma (T), breakage (B), and shortened tail (S). Swelling of the tail, not associated with skin damage was recorded as 'breakage' alongside tail deviation. All lesions and the zone affected were recorded.

2. 3. 7. 2 Measures assessed with the assessor in the feed passage

These included ocular and nasal discharge, and avoidance test (from 10th farm onward). Discharges were recorded based on the Wisconsin-Madison three-point system with score 2 being considered as significant discharge [49]. Avoidance test was done as per Crossley et al. [50]. Briefly, the assessor slowly (one step per second) approached the cows standing at the feed-face. Scores 2, 1, and 0 were given if the cow moved away with the assessor being ~>1 metre away, if the assessor was closer than 1 metre but before extending the hand toward the cow, and if the cow allowed the assessor to extend the hand or touch her, respectively.

2. 3. 7. 3 Measures assessed with the assessor in the milking shed

Teat hyperkeratosis was assessed from 13th farm onward using a 1-3 scoring system [51]. All four teats were scored, and the highest individual score assigned to the cow. Cows with a score ≥2 were recorded as having significant hyperkeratosis.

2. 3. 7. 4 Measures assessed with the assessor in the parlour exit

Locomotion scoring was done at the parlour exit on cows returning to their pens after milking using a 4-point scale [52]. Cows were recorded as lame if score was ≥2 and severely lame if score was 3.

2. 3. 7. 5 Stockperson Behaviour

Stockperson behaviour was assessed visually during milking time and when the cows were taken from the pen to the collecting yard. The researcher stayed in a nearby pen to keep a reasonable distance to avoid interfering with stockperson routines to ensure behaved as naturally as possible. The stockperson was not informed that their handling skills were being monitored. Stockperson behaviour was classified as 0 (not using force to move cows); 1 (moving cows using loud noises or hitting with tools) or 2 (moving cows with both loud noises and hitting).

2. 3. 8 Data handling and statistical analysis

All data were recorded on bespoke paper forms (see supplementary files) before being transferred to Microsoft Excel spreadsheets. Data were checked to ensure that no transfer error or mis-recordings were made. SAS version 9.4 (SAS institute, Cary USA) was used for all analyses except where otherwise stated. Descriptive statistics (mean, 95% confidence intervals for mean, minimum, maximum, median and interquartile ranges) were calculated for all measures, and boxplots created for measures divided by farm system (free stall vs bedded pack) and farm size (categorised using tertiles). For illustration purposes, where it was thought to be useful to further evaluate the effect of farming system or farm size on a welfare outcome, a generalised linear mixed model (binomial distribution with a logit link) was used with prevalence of welfare as the outcome and farm size or system as the predictor variable and farm as a random effect. This modelling was undertaken using SPSS version 29 (IBM, Armonk USA).

2. 4 Results

Overall, 94 farmers were contacted, and 63 farms were visited in the five provinces: Tehran (n=37), Alborz (n=15), Isfahan (n=3), Qazvin (n=4), and Qom (n=4). Between May and September 2022, 58 farmers were approached, and 53 agreed to be visited. After the death of Mahsa Jina Amini on 16 September 2022, nationwide pro-human rights uprisings followed, and the study paused for 4 months. Farmers were contacted again from January 2023, with 36 being approached but only 10 agreeing to a visit.

Separating farms into three size categories using tertiles resulted in small farms having ≤180 lactating cows, medium farms having 181 to 899 lactating cows, and large farms having ≥900 lactating cows. Data related to one small farm were lost, so data were available for analysis from 62 farms.

On the first five farms, data collection (sample size as per Cook [44], with four assessors, took between 2-4 working days per farm. After reduction in sample size to that recommended by Welfare Quality [41], all assessments were completed in one working day with two assessors. Table 2-1 shows the number of animals scored for each measure and the number of farms assessed. Table 2-2 shows the distribution of the farm-level prevalence of animals with different welfare issues across all assessed farms.

2. 4. 1 Nutrition

Median (interquartile range; IQR) herd level BCS was 2.75 (2.75 to 2.88). Maxi-mum herd-level prevalence of cows with a BCS of <2 and >4 was 7.8% and 5.1%, respectively (Table 2-2).

Table 2-1- The number of animals scored, and the number of farms assessed for each welfare measure in a cross-sectional study of 62 Iranian dairy farms

Domain		Indicator *	No. animals	No. farms
Nutrition		BCS ** [1]	4788	61
Physical Environment	Body Hygiene	Lower Leg [1]	4803	62
		Upper Leg [1]	4803	62
		Udder [1]	4802	62
		Tail [1]	4803	62
Health	Hock Lesions	Hock Hair Loss [1]	3473	55
		Hock Ulcer [1]	3474	55
		Hock Swelling [1]	3477	55
	Skin Injuries	Hock [1]	4804	62
		Knee [1]	4806	62
		Neck [1]	4806	62
		Back [1]	4805	62
		Other Parts [1]	4803	62
		Ear Damage [1]	2854	47
		Nasal Discharge [2]	4236	50
		Ocular Discharge [2]	4346	50
		Teat Hyperkeratosis [3]	3676	49
		Tail Damage [1]	4796	61
		Locomotion Score [4]	14,172	61
Behavioural Interactions		Avoidance Test [2]	4404	50

* Numbers represent the scoring location: 1) inside pen; 2) feed alley; 3) inside parlour; 4) parlour exit.

** Body Condition Score using the 1 to 5 UK system.

Table 2-2- Distribution of the farm-level prevalence of animals with different welfare problems in a cross-sectional study of 62 Iranian dairy farms

Welfare	Domain	Measure	Mean	Lower CI	Upper CI	1^{st} Quartile	Median	3^{rd} Quartile	Minimum	Maximum	No. of farms
Nutrition (BCS)		Lean Cows	0.49	0.19	0.79	0	0	0.91	0	7.84	61
		Fat Cows	0.21	0.00	0.43	0	0	0	0	5.13	61
Health	Tail Damage		59.1	53.7	64.5	43.1	60.0	76.9	6.7	100	61
	Locomotion Score 2 (Clinically Lame)		31.3	28.1	34.5	22.5	30.8	37.1	7.4	66.8	61
	Locomotion Score 3 (Severely Lame)		4.04	30.3	5.04	1.20	3.0	6.50	0	22.1	61
	Hock (tarsal joint) Lesions	Hair-loss	38.3	31.7	44.9	17.8	36.0	51.8	0	97.9	55
		Swelling	41.5	35.4	47.6	23.5	40.7	60.9	0	87.9	55
		Ulcer	4.25	2.43	6.07	0	1.92	6.63	0	41.0	55
	Skin Injuries	Knee (carpal joint)	28.0	21.2	34.9	6.33	16.8	46.7	0	97.4	62
		Neck	7.91	5.17	10.7	0	3.50	9.84	0	38.3	62
		Back	5.64	4.24	7.05	2.20	4.30	7.02	0	31.1	62
		Other parts	25.3	21.3	29.4	13.7	23.4	32.3	0	81.8	62
		Ear Damage	20.5	14.7	26.3	7.25	13.5	25.0	1.41	100	45
	Discharges	Nasal	8.89	5.84	11.9	1.70	6.20	11.6	0	65.2	58
		Ocular	14.5	11.6	17.5	6.50	12.8	19.7	0	52.4	60
	Teat Hyperkeratosis		23.0	15.9	30.1	4.15	8.73	42.3	0	91.2	48
Environment	Dirty Body Parts	Lower Leg	96.8	94.4	99.1	98.9	100	100	48.6	100	62
		Upper Leg	86.8	81.8	91.7	80.0	95.7	100	21.1	100	62
		Udder	74.3	67.4	81.2	59.0	83.6	97.8	7.62	100	62
		Tail	86.0	80.9	91.1	81.7	95.1	98.9	24.8	100	62
Behavioural Interaction		Avoidance 0	39.2	35.1	43.4	28.0	38.9	53.0	4.30	79.2	60
		Avoidance 1	24.7	21.6	27.8	15.2	22.9	33.7	4.20	52.7	60
		Avoidance 2	36.1	31.7	40.5	21.1	36.4	46.6	3.70	70.4	60

2. 4. 2 Physical Environment

2. 4. 2. 1 Body hygiene

The lower part of the leg was the dirtiest part of body (median farm level prevalence: 100%), while udder was the least dirty part (median farm level prevalence: 83%; Table 2-2; Figure 2.3). Prevalence of dirty body parts was apparently unrelated to the farming system. Farm-level median (IQR) prevalence of dirty body parts in free-stall (FS) vs bedded-pack (BP) farms were 100% (99.5 to 100%) vs 100% (98.6 to 100%) for lower legs, 91.2 % (72.4 to 97.1%) vs 97.1% (86.7 to 100%) for upper legs, 71.8% (44.8 to 88.7%) vs 90.0% (66.7 to 98.6%) for udders, and 95.4% (79.4 to 98.8%) vs 94.6% (80.0 to 98.6%) for tails, respectively.

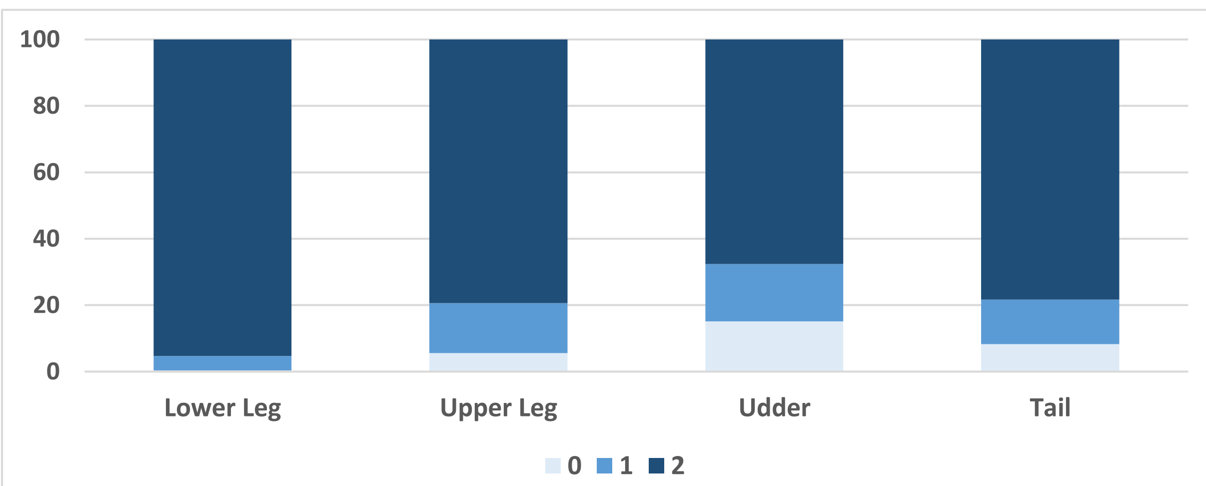

Figure 2.3. Prevalence of damaged tails in 62 Iranian dairy farms in a cross-sectional welfare assessment study. Breakage includes swellings and deviations; Other damage includes trauma and shortened tails.

2. 4. 3 Health

2. 4. 3. 1 Tail Damage

All farms had cows with damaged tails. Farm level prevalence ranged from 6.7 to 100% (Table 2-2; Figure 2.3).

Breakage was the most prevalent form of tail damage accounting for 92.8% of all tail problems, with 4.5% of animals with tail damage having shortened tails and 2.7% having trauma (Figure 2.5). Of the 4796 cows who were scored for tail damage, 33% had one breakage, 15% had 2 breakages, and 5% had ≥3 (see Figure 2.6 for cow-level prevalence of tail damage). Our data were compatible with no effect of farm size or farming system on the prevalence of tail damage (see Table 2-3 and Table 2-4).

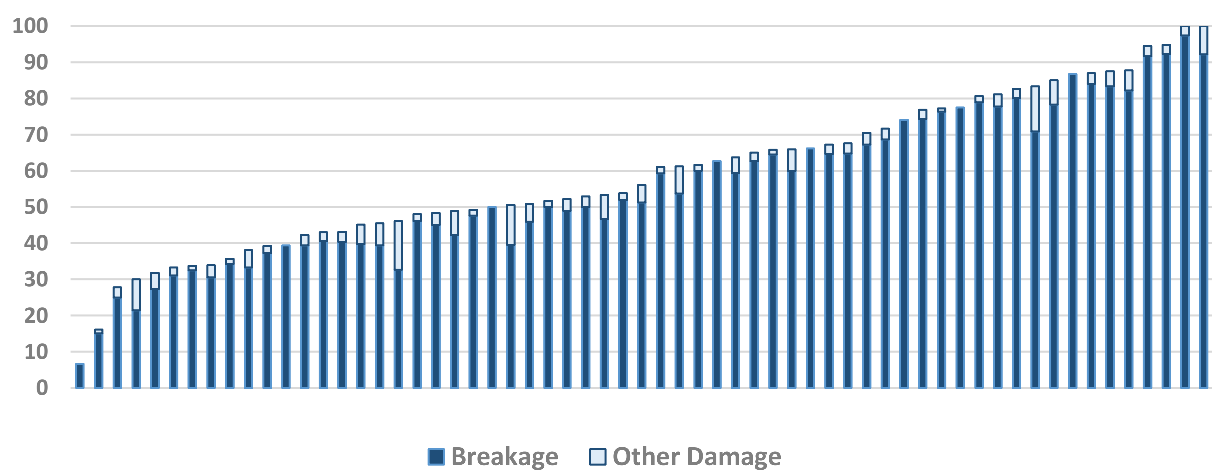

Figure 2-4- Relative frequency of each hygiene score in different parts of the body in a cross-sectional study of 62 Iranian intensive dairy farms. Score 0: <5% of the body part is dirty; score 1: 5 to 25% of the body part is dirty; score 2: >25% of the body part

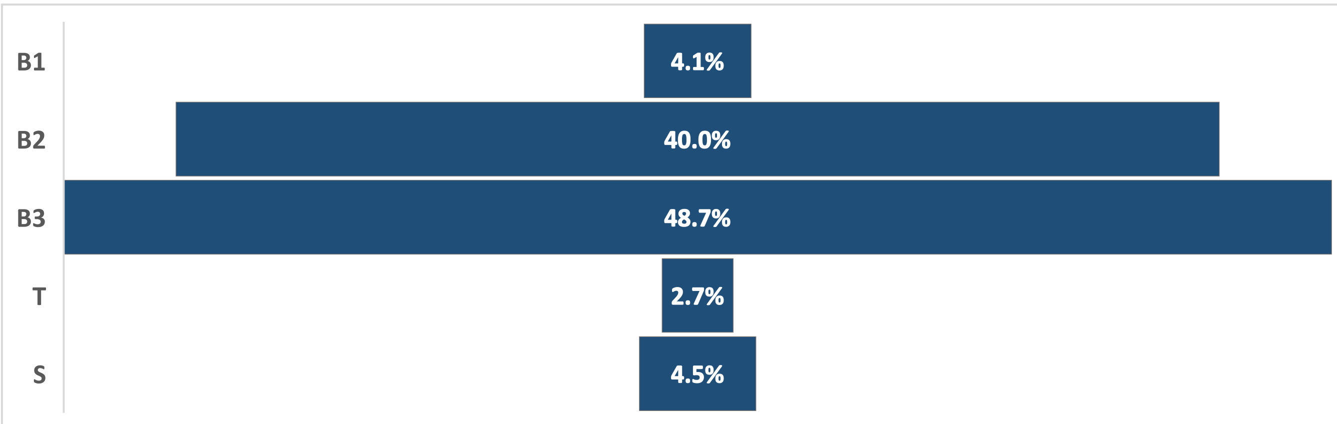

Figure 2.5. Relative frequency of different types of tail damage in a cross-sectional welfare assessment study of 62 Iranian dairy farms. B1: breakage in zone 1 of the tail (i.e., the top one-third of the tail); B2: breakage in zone 2 of the tail (i.e., the middle one-third of the tail); B3: breakage in zone 3 of the tail (i.e., the lower one-third of the tail); T: trauma; S: shortened

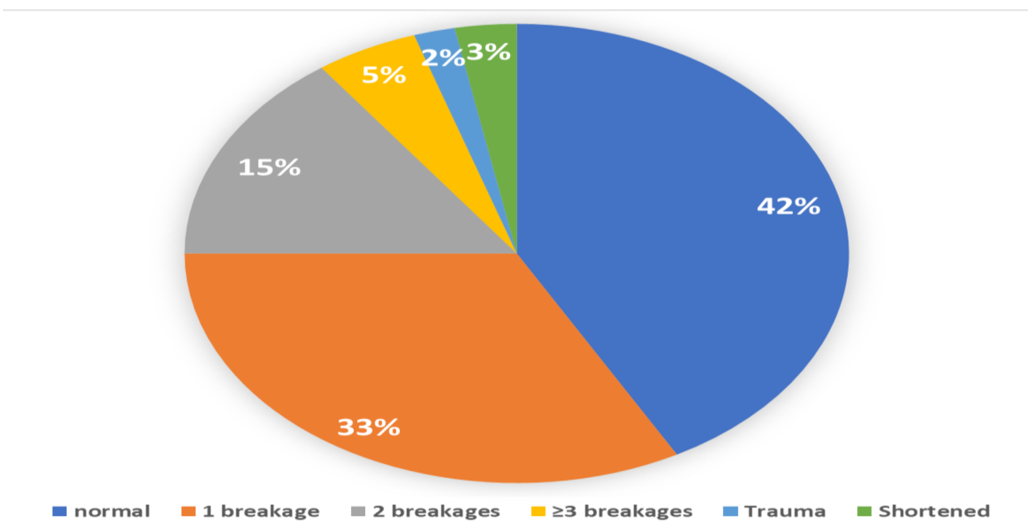

Figure 2.6. Proportion (cow-level prevalence) of animals with different tail conditions in a cross-sectional welfare assessment study of 62 Iranian dairy farms

2. 4. 3. 2 Locomotion Score

Median (IQR) within-farm prevalence of lameness (cows with locomotion scores 2 and 3; ≥LS2) was 32.9% (26.0 to 42.1%). Table 2 shows the prevalence of LS2 and LS3 cows. There were no severely lame animals (LS3) on 12/62 farms (Figure 2.7). Of these 12 farms, ten had ≤180 lactating cows, and two had ≥900 lactating cows. Nevertheless, our data were consistent with no effect of farm size or farming system on the prevalence of lameness (Table 2-3 and Table 2-4).

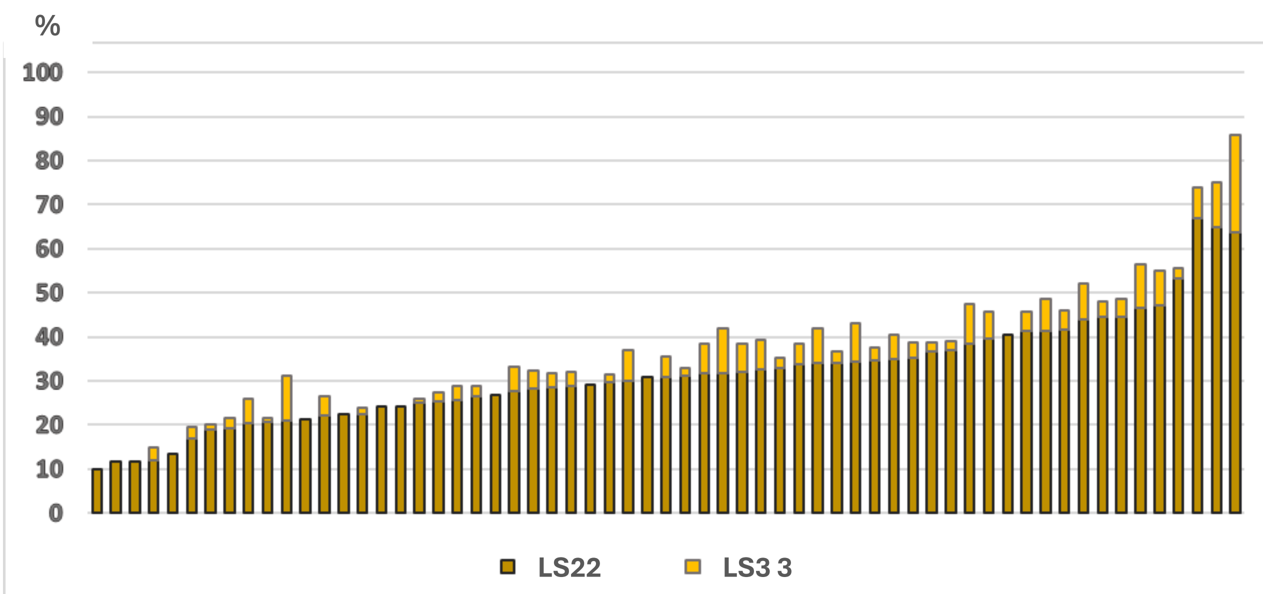

Figure 2.7. Prevalence of lameness in 62 Iranian dairy farms in a cross-sectional welfare assessment study. LS2: locomotion score 2 out of 3 (i.e., clinically lame cows); LS3: cows with locomotion score 3 out of 3 (i.e., severely lame cows)

Table 2-3- The effect of different farming systems and farm sizes on the prevalence of tail damage, lameness, and hock lesions in a cross-sectional study of 62 Iranian dairy farms

Indicators	Farming System[a]	Exp (Coefficient)	95% CI Exp (Coefficient) Lower	95% CI Exp (Coefficient) Upper	p value
Farming System					
Tail Damage	Freestall	1.03	0.77	1.36	0.86
	Bedded-Pack [b]	.	.	.	-
Lameness	Freestall	0.91	0.74	1.12	0.37
	Bedded-Pack [b]	.	.	.	-
Hock Hair-loss	Freestall	3.82	2.37	6.13	<.001
	Bedded-Pack [b]	.	.	.	.
Hock Swelling	Freestall	2.56	1.60	4.10	<.001
	Bedded-Pack [b]	.	.	.	.
Hock Ulcer	Freestall	2.35	1.18	4.70	0.02
	Bedded-Pack [b]	.	.	.	.
Farm Size					
Tail Damage	Small	1.32	0.71	2.46	0.37
	Medium	0.97	0.66	1.45	0.89
	Large [b]	.	.	.	.
Lameness	Small	0.83	0.53	1.28	0.39
	Medium	0.87	0.63	1.21	0.40
	Large [b]	.	.	.	.
Hock Hair-loss	Small	0.63	0.28	1.45	0.27
	Medium	0.55	0.24	1.29	0.16
	Large [b]	.	.	.	.
Hock Swelling	Small	0.76	0.36	1.59	0.45
	Medium	0.83	0.39	1.78	0.63
	Large [b]	.	.	.	.
Hock Ulcer	Small	0.96	0.37	2.48	0.93
	Medium	0.56	0.21	1.50	0.24
	Large [b]	.	.	.	.

a- farm is considered as a random effect in the model
b- this coefficient is set to zero because it is redundant as it is the reference category for the odds ratio

Table 2-4- Distribution of herd-level prevalence of animals with different welfare issues in free-stall and open-shed farms in a cross-sectional study of 62 Iranian dairy farms

Measure		Category	Mean	Lower 95% CI	Upper 95% CI	1st Quartile	Median	3rd Quartile	Minimum	Maximum
Tail Damage		Free-stall	55.1	46.9	63.3	37.5	57.3	69.6	16.1	100
		Bedded-pack	60.6	53.3	67.9	46.6	55.5	80.9	6.7	100
Lameness		Free-stall	39.6	32.9	46.3	28.1	37.6	46.7	10.1	85.7
		Bedded-pack	31.4	27.3	35.4	24.1	30.8	38.6	8.2	56.5
Hock (tarsal joint) Lesions	Hair-loss	Free-stall	56.2	47.5	64.9	43.7	51.7	74.3	16.7	97.9
		Bedded-pack	25.4	18.7	32.1	14.7	23.3	36.0	0	95.5
	Swelling	Free-stall	54.5	46.1	62.9	38.3	54.6	66.2	22.9	87.9
		Bedded-pack	32.6	25.5	39.7	17.5	28.8	45.3	0	73.3
	Ulcer	Free-stall	7.09	3.18	11.0	1.10	3.75	10.3	0	41.0
		Bedded-pack	2.35	1.12	3.58	0	1.18	3.51	0	17.1

2. 4. 3. 3 Hock lesions

Overall, median (IQR) prevalences of hair-loss on the left hock alone, right hock alone, or both hocks (Table 2-2; Figure 2.8) were 8.1% (5.9 to 11.8%), 3.9% (2.8 to 7.3%), and 17.5% (6.6 to 35.0%), respectively. The same figures for swelling were 7.5% (4.4 to 13.3%), 1.7% (0.0 to 3.2%), and 24.1% (13.3 to 45.5%), respectively, and for ulcer were 0% (0 to 1.9%), 0% (0.0 to 1.7%), and 0% (0 to 0.9%), respectively.

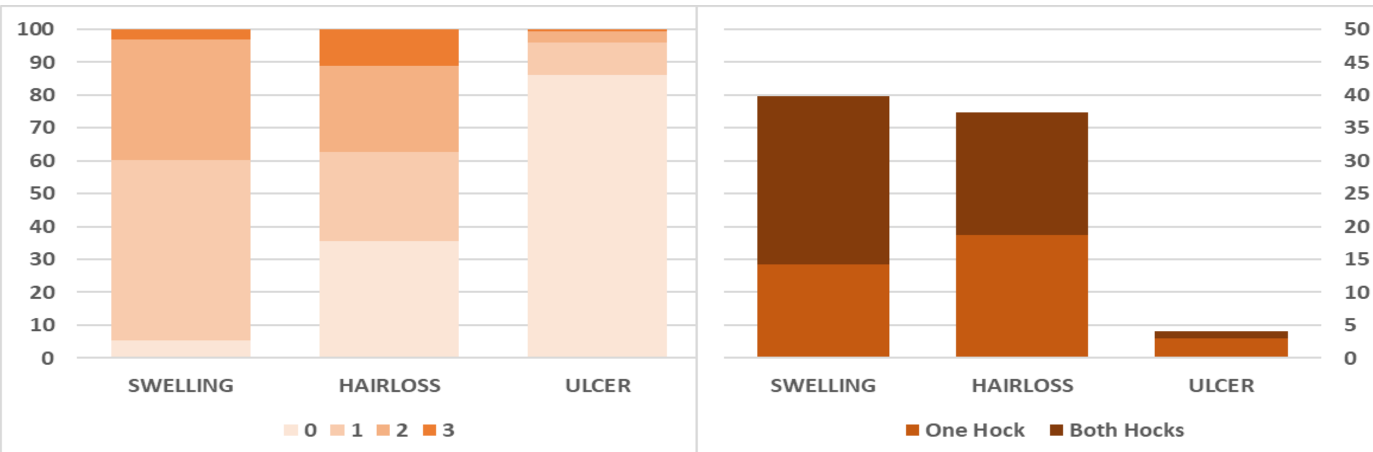

Figure 2.8. Relative frequency of hock lesion scores (Left) and farm prevalence of severe hock lesions in either left or right foot only or in both feet (Right) in a cross-sectional welfare assessment of 62 Iranian dairy farms. Scoring was done as per Potterton et al. [2] where score 0 means an absence of a lesion on the hock (dorsal joint), score 1 is mild lesions, and scores 2 and 3 show severe lesions

Effect of farm system on hock lesions is summarised in Figure . Compared to BP farms, odds of having hair loss, ulcer and swollen hock on FS farms were all higher (OR 3.82 (95% CI: 2.37 to 6.13), 2.35 (95% CI: 1.18 to 4.70), and 2.56 (95% CI: 1.60 to 4.10), respectively). In contrast, our data were consistent with no effect of farm size on the prevalence of any hock lesion type (Table 2-3 and Table 2-4).

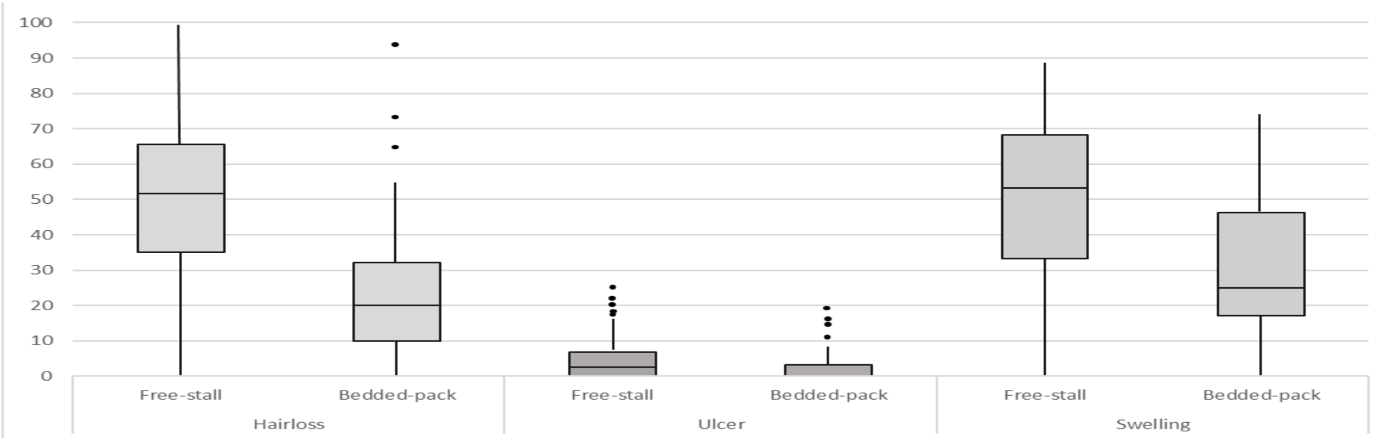

Figure 2.9. Distribution of prevalence of hock lesions in free-stall and bedded-pack farms in a cross-sectional study of 62 Iranian dairy farms

2. 4. 3. 4 Injuries on knees, back, neck, and other body parts

Table 2-2 summarises the prevalence of integument alterations and ear damage across the farms. Back and neck injuries had the lowest prevalence (median farm-level prevalence of 3.5 and 4.3%, respectively).

2. 4. 3. 5 Ear Damage

Median (IQR) of ear damage across all farms was 13.5% (7.3 to 25%). While there were 7 farms with <5% prevalence of damaged ears, 3 farms had a prevalence of >50%.

2. 4. 3. 6 Nasal and Ocular Discharges

Median (IQR) within-farm prevalence of cows with significant nasal and ocular discharges was 6.2% (1.7 to 11.6%) and 12.8% (6.5 to 19.7%), respectively (Table 2-

2). There were 10 /58 and 3/60 farms that had no cows with significant nasal or ocular discharges, respectively.

2. 4. 3. 7 Teat Hyperkeratosis

Median (IQR) within-farm prevalence of cows with severe teat hyperkeratosis was 8.7% (4.2 to 42.3%; Table 2-2). There was a wide variation in farm-level prevalence of teat hyperkeratosis (ranging from 0 to 91%) with only one farm having no cows with hyperkeratotic teats.

2. 4. 3. 8 Stockperson behaviour (direct measurement of human-animal relationship)

Direct measurement could not be done on 2/62 farms as the time of measurement coincided with other welfare assessments. In 8/60 farms handling with no hitting or loud noise was observed, while 15/60 farms used either hitting or making loud noises. In 37/60 farms, stockperson used both hitting and shouting/ loud noises, and in 3/60 farms violent behaviour was observed (i.e., hitting the animal in sensitive parts such as the head, or hitting too hard to deliberately hurt the animal).

2. 4. 3. 9 Avoidance Test (indirect measurement of human-animal relationship)

Table 2-2 shows the within farm prevalence of animals with different human-animal interactions. Median (IQR) within-farm prevalence of cows that allowed the researcher to touch them (avoidance 0) and those who had high flight zones (avoidance 2) were 38.9% (28.0 to 53.0%) and 36.4% (21.1 to 46.6%), respectively.

2. 5 Discussion

This is the first systematic assessment of welfare on Iranian dairy farms. Previous studies have assessed some of the animal-based measures assessed in this study, such as BCS [53,54] and lameness (e.g. Mohammadnia et al. [22]), but no previous study has recorded and compared multiple welfare measures on individual farms. This lack of a focus on welfare assessment was reflected in the lack of knowledge of the term 'animal welfare' by many of the farmers involved in this study, with the term "welfare" (In Persian: Refa`h; رفاه) often being confused with "comfort" (In Persian: Asayesh; آسایش). This familiarity with the term 'comfort' rather than animal welfare may be related to the regular "Cow Comfort and Lameness" congress that has been held regularly in Iran since 2015.

2. 5. 1 Nutrition

In this dataset there were very few cows that were too lean or too fat. This is unsurprising as for intensively managed dairy cattle, ensuring feed availability is an essential part of optimising milk production [55] and 61/62 farms employed a full-time nutritionist or a nutrition consultant. Furthermore, measurement of BCS has long been used as a practical management tool on Iranian dairy farms, with target BCS of 3.5 to 4 in fresh cows and 3 to 4 in other production groups (markedly different from our welfare thresholds). Body condition score was the only directly nutrition-related animal-based measure included in the assessment. Since BCS is reflective of medium/long-term nutrition status of the animal, it is often recommended to be used alongside shorter-term indicators as rumen fill score [56]. However, much of the variation in rumen fill score is not related to feed intake limiting its value as a welfare measure.

2. 5. 2 Physical Environment

2. 5. 2. 1 Body hygiene

This study reported a high prevalence of dirty animals consistent with (although at the high end of) results from housed cattle across the world [57-59]. Despite free stall systems being designed to improve cow cleanliness [60], we found no clear difference at the univariable level between farm systems in the proportion of dirty cows. This suggest in both systems that walking alley cleanliness on many Iranian dairy farms is inadequate and that existing cleaning technologies are often ineffective. Our data strongly suggest that more attention needs to be paid to farm hygiene on many Iranian dairy farms.

2. 5. 3 Health

2. 5. 3. 1 Tail damage

Few studies have reported the prevalence of tail damage in dairy cows, with the reported prevalence of tail damage varying from 4% on Uruguayan dairy farms [61] to 46% in a study done in a single US dairy farm [62]. Although direct comparison across studies is complicated by the lack of precise definitions of tail damage, the use of observation in some studies and palpation in others, and the inclusion/exclusion of docked tails. The median herd level prevalence of damaged tails in our study population was 60%. This is much higher than any other previous report. In particular, it is much higher than the 14.9% reported by Cuttance et al [63] who used a modified NZVA tail score. This difference may actually be larger as Cuttance et al [63] used palpation/observation whereas we used observation alone (which probably identifies fewer cows with tail damage; AJ-Gh, personal observation). It is unclear from this analysis what is driving the high prevalence of tail damage on dairy farms. Neither herd size nor system affected prevalence at the univariable level. Further research is required to establish the risk factors for tail damage on Iranian dairy farms. This should be combined with a standardisation of the tail scoring process and a test of its repeatability and reliability.

2. 5. 3. 2 Locomotion scoring

The median herd level prevalence of lame cows (score ≥2) was 33%, lower than the 52.2% reported by Mohamadnia et al [22] across three Iranian dairy herds, but higher than the median of 22% identified by a systematic review of worldwide lameness prevalence [64]. In contrast the median herd level prevalence (3.1%) of severely lame cows (LS=3) was lower than the median prevalence of severe lameness (6.5%) reported in that review. It is clear that there is a significant effort to improve lameness and control it on Iranian dairy farms.

2. 5. 3. 3 Hock lesions

As in previous studies [47], we found that swelling and hair loss were much more common than ulceration. The prevalence of hock lesions in this study are similar to those reported on Chinese farms [65] and on farms in British Colombia [66]. Nevertheless, these results indicate that hock lesions are a significant welfare problem on many Iranian farms. We identified a much higher prevalence of hock lesions on freestall farms than on bedded pack farms, consistent with previous studies [67,68], so focusing on freestall farms and identifying why some freestall farms have a much higher level of hock lesions than others could appreciably improve welfare on Iranian freestall farms.

2. 5. 3. 4 Injuries on knees, back, neck, and other body parts

While injuries can be important indicators of dairy cattle welfare on farms, there is a clear lack of data in the literature regarding the prevalence of such injuries. Our results for knee, back and neck injuries are consistent with prevalences reported in other systems with intensively managed dairy cows [69-71].

2. 5. 3. 5 Ear damage

Our study showed that a high number of cows (median of 13.5%) in this survey had damaged ears, and that all farms had cows with damaged ears (range 1.4 to 100%). We speculate that this may have been related to ear tags being pulled out, but ear tags are commonly used worldwide [72], and if they did routinely result in ear damage in almost

1/8 tagged cows, we would have anticipated that there would have been previous reports of such damage. Further investigation is required.

2. 5. 3. 6 Nasal and ocular discharges

The median prevalence of cows with severe nasal discharge (6.2%) was consistent with previous reports which have ranged between 0 and 16.5% [73,74], but the prevalence of ocular discharge (12.8%) is higher than previous reports (0- 5%; [73-75]. This may be due to the environment that predominated on Iranian dairy farms, but this needs confirming by further investigation.

2. 5. 3. 7 Teat hyperkeratosis

Mein et al [51] set targets of ≤20% of animals with both moderate and severe teat hyperkeratosis and <10% of animals having severe teat hyperkeratosis. In our study population 18/49 farms failed to meet the target for moderate/severe lesions, while 4/49 had too many severe cases. These data suggest that attention to teat health is required on a substantial percentage of Iranian dairy farms.

2. 5. 4 Human-Animal relationship

2. 5. 4. 1 Stockperson behaviour (direct measurement of human-animal relationship)

On most farms (62%), cows were moved from their pens to the milking parlour using a combination of loud noises and hitting, with only 13% of farms using neither approach. This is higher percentage of issues than reported by Sapkota et al [76] on

New Zealand dairy farms and is more reminiscent of the behaviour recorded by Leon et al. [77] in a slaughterhouse, where physical force (hitting/prodding; 49%) and shouting (13%) were the most common ways to interact with the cows. This high level of aversive stockpersonship during milking (when cows are voluntarily moving) suggests that here may be even more issues at times when cows are more reluctant to move (e.g. entering the trimming chute during hoof trimming; [78]) We need further data on the quality of stockpersonship on Iranian dairy farms and the factors driving it, but it is clear from our interactions with farm staff during the study that lack of training is likely to play a major role.

2. 5. 4. 2 Avoidance Test (indirect measurement of human-animal relationship)

In contrast to our direct assessment of human-animal relationship, the avoidance test showed that almost 2/3 of cows did not have large flight zones. This is consistent with Waiblinger et al. [11] who found that stockperson behaviour when moving the cows from their pens to the milking parlour was not related to the cows' avoidance distance. In addition, the high human to animal ratio on many of the study farms may also be related to the low avoidance distance [79]. Further investigation is needed to confirm this hypothesis.

2. 6 Conclusion

This study assessed different aspects of dairy cattle welfare in 62 Iranian dairy farms in arid and semi-arid regions in Iran. The low prevalence of cows with very low or very high BCS confirm the focus on nutrition management on Iranian dairy farms. Other aspects of welfare such as body hygiene and skin injuries were relatively close to what is seen on North American farms. Lameness prevalence and the incidence of hock lesions are also similar to many zero-grazed farms outside Iran but are too high and need more attention. Finally, the extremely high median prevalence of tail damage (60%) indicates a significant welfare issue that needs to be addressed with urgency. Overall, our results indicates that Iranian dairy farmers would hugely benefit from more education regarding dairy cattle welfare.

Author Contributions: Conceptualization, A.J-Gh. and R.L.; Methodology, A.J-Gh. and R.L.; Protocol Development, A.J-Gh., R.L., F.KH., S.J-Gh., and M.H.M.; Data Gathering and Handling, A.J-Gh., F.KH., S.J-Gh., and M.H.M.; Formal Analysis, A.J-Gh., R.L., and E.V.; Writing – Original Draft Preparation, A.J-Gh.; Writing – Review & Editing, A.J-Gh., R.L., K.M, M.D.B, and E.V.; Supervision, R.L., K.M, M.D.B, and E.V.; Project Administration, R.L.; Funding Acquisition, R.L. and A.J-Gh.".

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Informed Consent Statement: Informed consent was obtained from all farmers involved in the study.

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Ali: Conceptualisation, Methodology, Protocol Development, Investigation and Data Curation, Formal Analysis, Writing, Funding Acquisition
Richard: Conceptualisation, Methodology, Protocol Development, Formal Analysis, Writing (editing), Funding Acquisition, Project Administration, Supervision
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Chapter 3

An Investigation of Dairy Cattle Welfare in Commercial Iranian Farms: Results from Resource-Based Measures and Farm Records

Presented in part in the following conference:

Jafari-Gh, A., Laven, R., Khaloubagheri, F., Jafari-Gh., S., Mirrahimi, S.M.H., Dehghan-Banadaki, M., Muller, K. and Vallee, E., 2025. Investigating dairy cattle welfare on intensive farms: feed and water availability. American Dairy Science Association annual meeting, Louisville, Kentucky, USA

Jafari-Gh, A., Laven, R., Khaloubagheri, F., Mirrahimi, S.M.H., Jafari-Gh., S., Dehghan-Banadaki, M., Muller, K. and Vallee, E., 2025. Investigating dairy cattle welfare on intensive farms: cow flow management. American Dairy Science Association annual meeting, Louisville, Kentucky, USA

3. 1 Abstract

There is currently no routine systematic assessment of welfare on Iranian dairy farms and no industry-recognised welfare assessment protocols. Therefore, we aimed to design a comprehensive welfare assessment protocol and use it to assess dairy cattle welfare on Iranian dairy farms that could serve as baseline data. This paper focuses on assessment of resources on 4 critical areas of housing, water and feed availability, cow flow management, and hoof health management as well as collecting the data recorded by the farmers (e.g., incidence of lameness and mastitis). Cows were milked 3 times a day in 53/58 farms, which resulted in them spending a considerable amount of time away from the pen. Out of the 54 farms on which the time away for milking was measured, 14 had cows spending ≥4 hours a day for milking. Additionally, 17/43 farms provided <6 cm of water trough length per cow, and 9/46 farms provided <47 cm of feed trough length per cow, falling short of international guidelines. Hoof trimming was considered a routine procedure with 51/56 farms trimming the hooves ≥2 times a year, and it was done either by external contractors (29/50) or farm staff (21/50). Cow flow management was suboptimal as 23/48 farms deprived their cows of a good transfer passage (i.e., no holes or potential hazards). The main housing problem in bedded-pack farms was lack of resting area with 18/29 farms providing less space than the minimum requirement of 5.4 m^2, while in free-stall farms bedding depth was the principal housing issue with 16/28 providing ≤10 cm of bedding.

Finally, only 31/42 farms that provided farm data kept a record of more than half of the records that we asked for, and the accuracy of much that recorded data is debatable. Our findings highlight significant disparities in cow welfare among the farms and demonstrates the need to move from high level and broad assessments to a more in-depth welfare assessment on Iranian farms.

3. 2 Introduction

The change from pastoral/semi-pastoral systems to confined housing systems in many countries has resulted in significant challenges for the dairy industry [80]. These include multiple animal-welfare related challenges, with particular issues related to lameness, mastitis, lying behaviour, cow-cow aggression, feed availability and metabolic disease [81-83]. These challenges, and the perception that housed systems are less natural [32] have resulted in intensive housed systems being the principal focus of most welfare assessment schemes for cattle [41].

Most intensive dairy farms in Iran are located in parts of the country where the climate is arid/semi-arid, and not suitable for grazing dairy cattle. Thus, in Iran, housed dairy cattle produce the majority of milk (approximately 5 million tons of milk of a total of 8.4 million tons produced in the country; personal communication). Despite this, there is no industry-recognised welfare assessment scheme and no routine systematic assessment of welfare on Iranian dairy farms.

In our previous paper [84], we described the development of a welfare scheme designed to create baseline data of the welfare of housed dairy cattle in Iran. In that paper we focused on animal-based and stockmanship measures and showed that 'animal welfare' was not a term with which farmers/farm managers were familiar. We found that some animal-based welfare indicators such as body condition score (BCS) were managed well by the farmers (though for production rather than welfare reasons), while some other indicators such as tail damage were neglected.

Animal-based measures are a crucial part of welfare assessment because they are considered a direct and 'outcome'-based way to assess animal welfare [85]. However, there are some limitations to animal-based measures. For example, not all welfare issues can be identified on a single visit using animal-based measures [85]. Therefore, farm records can be useful because they can provide a timeline of treatments and health interventions (such as mastitis or lameness), as well as detailing the number of deaths and injuries alongside reproductive performance and productivity.

In addition, some potential welfare issues cannot be easily identified using animal-based measures. For example, unlike hunger which can be inferred using BCS and/or rumen fill with minimum stress to the cow, the presence of thirst cannot be easily evaluated at the animal level, so the risk of thirst is usually determined by measuring water availability [35], which is a resource-based measure. Such measures identify risks rather than outcomes so are useful for assessing situations where there is not currently a welfare problem but where there could be in the future. Examples of this include heat or cold stress – measuring shade and shelter can estimate the risk of temperature stresses even when the current ambient temperature is favourable. Assessing resources can also be useful even when animal-based assessment has identified a problem, as such assessment can identify key risk factors and areas for improvement. Therefore, the welfare protocol that we developed for intensive Iranian dairy farms [84] included resource-based measures and farm records alongside animal and stockperson-based measures. This paper presents a descriptive report of the outcome of our resource- and record-based assessments on 62 intensive dairy cattle farms in Iran.

3. 3 Material and Methods

All study procedures were approved by the Animal Ethics Committee of the College of Agricultural and Natural Resources, University of Tehran (protocol code 6765D and 22/06/2022).

3. 3. 1 Study Population

Data were gathered from 62 intensive dairy farms in arid and semi-arid provinces in Iran from May 2022 to March 2023. The aim was to visit at least 60 dairy farms (based on [34]). Farms were chosen using the snowball sampling method [44]. Detailed description of the sampling method is presented elsewhere [84].

3. 3. 2 Protocol Development

For the resource-based section of the protocol, papers published in North America were the key sources [66,69,86,87] alongside Welfare Quality [42] and a recent New Zealand study [36]. Two more informal sources were also used [88,89]. A shortlist was created and was tested before the study started [84]. The protocol was further changed and developed during the visits as the research team found an area of interest. As the protocol was still being developed during the farm visits, additional measures were added during the process. That means that not all measurements were made on all 62 farms.

3. 3. 3 Data Gathering Process

Data were gathered by four members of the research team: A.J-Gh. (PhD student), F.K (farmer, agronomist), S.J-Gh. (animal scientist), M.H.M (senior veterinary medicine student). All data were gathered in a way to minimize stress to the cows. For example, data regarding stall dimension or feed bunk space were gathered only when cows had left the barn for milking, and data regarding the condition of the transfer passages was only gathered when no cows were moving between their pens and the milking parlour. Data were put into five different categories: housing, water and feed availability, cow flow management, hoof health management, and farm records (see Figure 3.1).

3. 3. 3. 1 Housing

Measures assessed in this category can be divided into measures that that were recorded similarly on bedded-pack (BP) and freestall (FS) farms (i.e. cooling and ventilation) and measures specific to each system or recorded differently. The latter included resting area per cow (BP only), stocking density and stall dimensions (FS only), and bedding material and depth (both systems).

3. 3. 3. 1. 1 Cooling and ventilation

Presence or absence of sprinklers/soakers and fans inside the barn, over the troughs, in the parlour holding area, and inside the parlour were recorded separately. Damaged fans or damaged lines of sprinklers/soaker were recorded as "absent". In addition, the availability of shade (full shade if it covered the whole area, and partial if it did not) over the resting area and troughs were recorded separately.

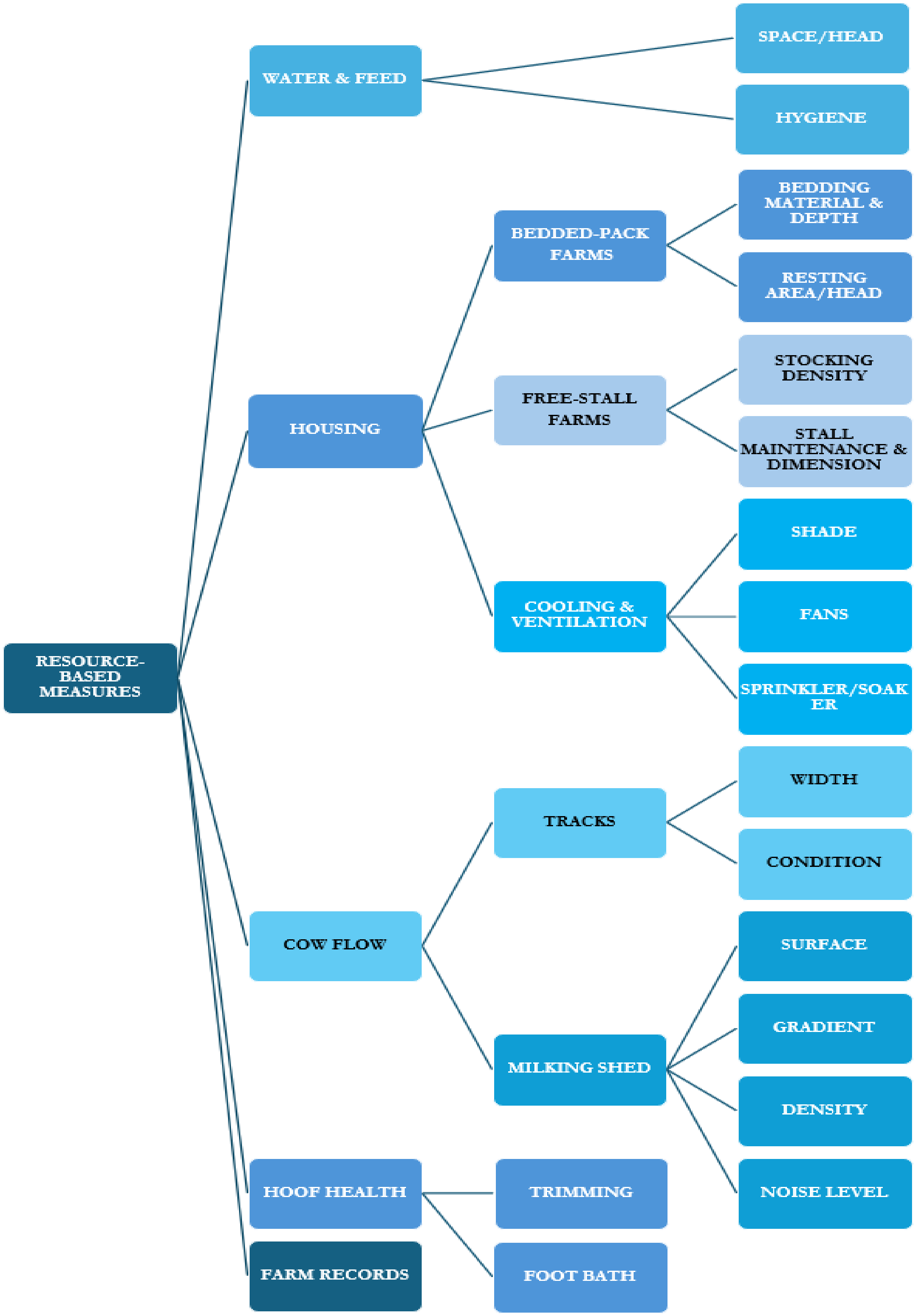

Figure 3.1 Resource-based measures assessed and the location of the assessments

3. 3. 3. 1. 2 Free-stall farms

Measures assessed in FS farms were done only in pens used to keep early lactation cows (i.e., cows with days in milk of ≤150), and included stocking density (i.e., ratio of cows to undamaged stalls reported as percentage as per [69]), bedding type and depth (at the shallowest part of a stall), presence of a dirty alley (alley covered by a layer of manure ≥2 cm) [87]), and stall dimensions [90], calculated from the average dimensions of 5 undamaged stalls. The presence/absence of non-usable stalls (damaged stalls that were too narrow, too wide, or had displaced stall bars) was also recorded.

3. 3. 3. 1. 2 Bedded-pack farms

Measures included average bedded area per cow of early lactation cows, bedding type, and bedding depth (as the shallowest part with an area of at least one square metre).

3. 3. 3. 2 Water and Feed Availability

Water trough cleanliness was recorded as per Welfare Quality [42], while feed trough cleanliness was assessed based on a 3-point scoring system: 0- no mould, manure, dirt, rubbish, or sign of contaminants; 1- small amount of old feed residue that could potentially grow mould (e.g., at the corners of the trough wall); 2- clear signs of mould, manure, dirt, trash, or any contaminant.

Both water and feed trough length were measured using a metal rolled tape, with only the usable length measured (e.g., if there was a barrier preventing cows accessing the float, this was not included). NRC [86] recommendations (47 cm/cow) were considered as the threshold for sufficient feed space and Welfare Quality recommendations [42] (6 cm per cow) for water space. Access to warm water during cold seasons, distance to water after milking, and the number of feed deliveries per day were also recorded.

3. 3. 3. 3 Cow Flow

Resource-based parameters that could potentially affect cow flow were measured and recorded in two distinct areas: transfer passages (pen to parlour), and milking parlour.

3. 3. 3. 3. 1 transfer passage

Transfer passage width (narrowest part), maximum walking distance to parlour (i.e., longest distance from the parlour exit to the end of a pen), the presence of sharp turns (>90° angles), the presence of narrow gateways (i.e., less width than the transfer passage), and condition of transfer passage were all recorded. Condition was categorised as good (no holes, bumps, or slippery surface), moderate (holes with approximately <10 cm diameter, uneven surface), or poor (major issues that could potentially harm the cows, e.g. holes with approximately >10 cm diameter, and slippery surface).

3. 3. 3. 3. 2 milking parlour

Parlour entrance and exit gradient was recorded as suggested by [91] and was considered good if the gradient was <10%, average if 10 to 15% gradient, and not acceptable if >15%). Parlour surface (*e.g.,* rubber mat or concrete), sharp turns in the entrance or at the exit (90^{o} angles if the exit transfer passage width was <3 metres), holding area surface quality (Figure 3.2), cows holding their heads up while waiting in the holding area [36], maximum return time (time between the first cow leaving the pen and the last cow returning to the pen [66]) were measured and recorded. Noise level was measured quantitatively as scored as 0 (two persons hearing each other clearly from one metre with normal voice), 1 (two persons hearing each other clearly from 2 metres), and 2 (two persons not able to hear each other clearly from <2 metres).

Figure 3.2. Different surface quality scores in parlour holding area- left: score 1: a smooth surface with potential chance of slipping; middle: score 2; non-grooved surface, but rough enough to avoid slipping; right: score 3; grooved concrete or rubber mats where chances of slipping are low

3. 3. 3. 4 Hoof Health Management

Information on hoof trimming frequency (the average number of trimmings per cow per year) and whether the trimmer was a farm worker or a trained contractor was collected. Availability of foot bath and a pre-wash bath were recorded, and data on foot bath frequency and the type of solution used collected.

3. 3. 3. 5 Farm Records

After the welfare assessment, the farmer/farm manager were asked to provide the following farm records: annual (from 21-03-2021 to 21-03-2022) recorded incidence of mastitis, lameness, culling, calf mortality, stillbirth, and current data on herd average 100-day in-calf rate, days open (DO), milk fat and protein yield, average milk production per cow (in litres/day), somatic cell count (SCC), mean lactation length, and current mean days in milk (DIM). All data were recorded as herd average

3. 3. 4 Statistical Analysis

All data were recorded on recording sheets before being transferred to Microsoft Excel. Data were double-checked to make sure that there were no transfer errors or misrecordings. Descriptive statistics (i.e., mean, 95% confidence intervals for mean, median, interquartile range, minimum, and maximum) were calculated and boxplots drawn using SAS version 9.4 (SAS Institute, Cary, NZ, USA). Bar charts and descriptive graphs were drawn using Microsoft Excel.

3. 4 Results

Overall, 63 farms were visited in arid and semi-arid regions in Iran: Tehran (n=37), Alborz (n=15), Isfahan (n=3), Qazvin (n=4), and Qom (n=4). Data from one farm in Tehran were lost. The remaining farms were put into three size categories based on tertiles (21 farms per category): small (<180 lactating cows), medium (181 to 899 lactating cows), and large (>900 lactating cows). The mean (95% CI) number of cows per pen in small, medium, and large farms were 48 (34 to 63), 89 (74 to 105), and 184 (157 to 211), respectively.

Across the 62 farms, 34 kept their fresh (approximate DIM ≤21) and early lactation cows (DIM approximately 22 to 150) in BP, while 25 farms kept them in FS and in 3 farms some fresh or early lactation cows were kept in FS and some of them in BP yards (mixed system; MIX). Of the 62 farms, 29 (17 FS, 10 BP, and 2 MIX) kept their fresh cows in a separate pen and then transferred them to a pen where early lactation cows were kept, while another 27 (7 FS, 19 BP, and 1 MIX) kept fresh and early lactation cows in the same pen, and 6 (1 FS and 5 BP) kept their cows from across lactation in the same pen.

As the protocol was still being developed during the farm visits, measures that were not initially included were added to the protocol as the research team realised an area of interest. Thus, not all measurements were undertaken on 62 farms.

3. 4. 1 Housing

3. 4. 1. 1 Cooling and ventilation

These measures were recorded on all 62 farms. The use of fans and sprinklers/soakers was observed on 43/62 and 39/62 farms, respectively, with 6 farms not using fans or sprinklers (1 FS and 5 BP). Fans were mostly used over the resting area (41 farms) and inside the parlour (43 farms), while sprinkler/soakers were mostly used over the feed troughs (39 farms), and in the holding area (32 farms) (summarised in Figure 3.3).

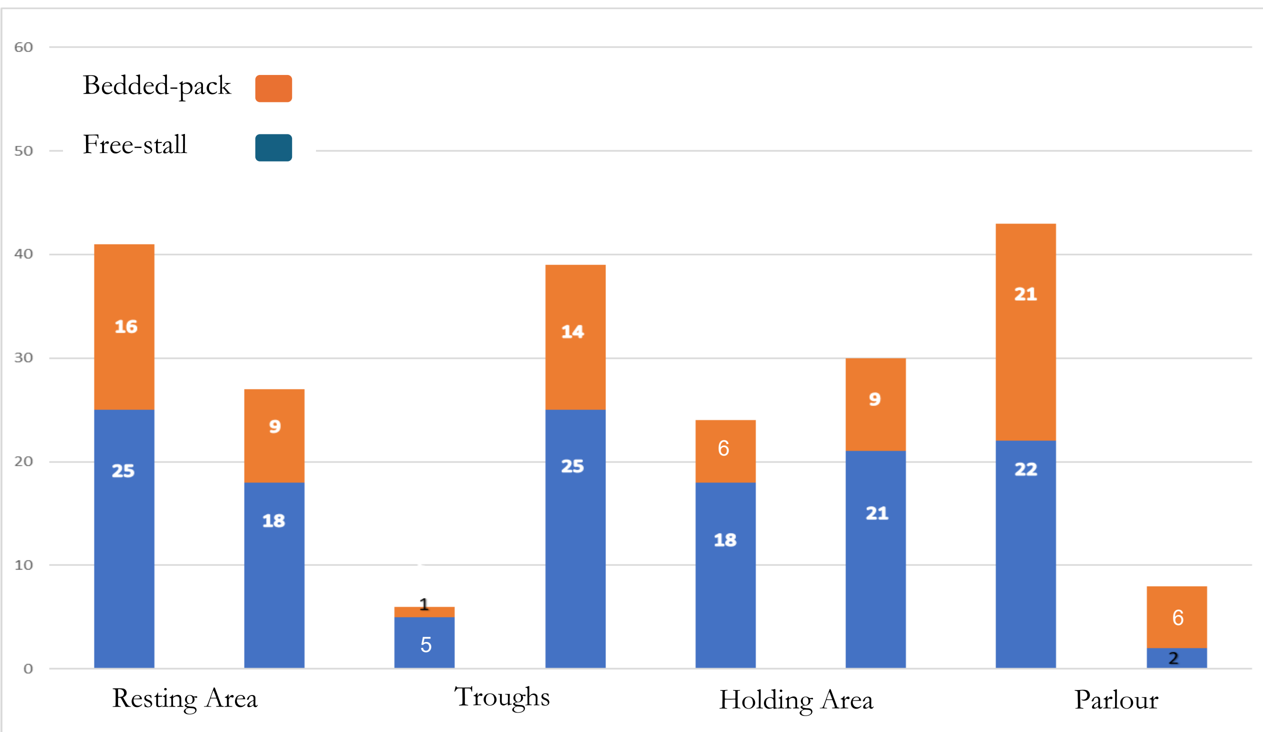

Figure 3.3. proportion of free-stall and bedded-pack farms that use fans (left bars) and sprinklers/soaker (right bars) in each section of the farm in a study of 62 Iranian dairy farms. Numbers inside the bars represent the number of farms in each farming system.

In 34 farms (21 FS, 12 BP, and 1 MIX) the feed troughs were completely shaded, while in 41 (22 FS, 18 BP, 1 MIX) the resting area was completely shaded. Partial provision of shade above the feed troughs was observed in 23 farms (4 FS, 17 BP, and 2 MIX) and above the resting area in 20 farms (3 FS, 15 BP, and 2 MIX). Five farms provided no shade above troughs and one no shade above the resting area (all BP farms).

3. 4. 1. 2 Free-stall farms

Data related to stall dimensions, and stocking density in the 28 farms which used FS (FS and MIX farms) are shown in Table 3-1. Median (interquartile range; IQR) stocking density was 95% (85 to 121%), i.e. 95 cows per 100 undamaged stalls. Damaged stalls were observed on 12/28 farms. Bedding materials used included dried manure (14/28), sand (12/28), and wood chips (2/28). The feed alley was dirty on 13/28 farms. All farms had concrete feed alleys except one farm which had installed rubber mats.

3. 4. 1. 3 Bedded-pack farms

Overall, 37 farms (34 BP and 3 MIX) kept fresh and early lactation cows on bedded packs. Figure 3.4 shows a typical pen on an Iranian BP farm. Dried manure was the only source of bedding on all farms for all lactation groups other than fresh (approx. DIM ≤21) cows. On 5/12 farms, fresh cows were kept on straw-topped manure, while on 2/12 farms they were kept on a mix of wood chips and dried manure solids, and in 5/12 farms fresh cows were kept on dried manure solids.

Figure 3.4. An example of a bedded-pack farm in Iran. The farm can be composed of multiple pens depending on farm size. Each pen has a bedded section where cows can rest and a big concrete walking area with access to feed and water troughs. The troughs are on the surrounding sides and are mostly accessible from outside the pen by a wide track where tractors and feeders can move. Dried manure solids are the main source of bedding.

The resting area available to fresh (approx. DIM ≤21) and early lactation cows (approx. DIM 22-150) were recorded in 9/12, and 29/32, respectively. Median (interquartile range; IQR) resting area per fresh cow was 808 cm2 (571 to 1042 cm2; n=9) and for early lactation cows was 463 cm2 (300 to 485 cm2; n=24). Table 3-1 summarises data regarding bedding depth and resting area per head in BP farms.

3. 4. 1 Water and Feed Availability

Feed and water trough hygiene were recorded on 62 and 61 farms, respectively, while feed trough length per head for fresh and early lactation cows was recorded on 17/29 and 46/62 farms, respectively. Additionally, water trough length per fresh and early lactation cow was recorded in 16/29 and 43/62 farms, respectively.

Figure 3.5 illustrates the distribution of the available feed and water trough length per cow on the study farms, and Table 3-1 provides the latter data as well as data regarding distance to water after parlour exit. All farms had at least one water trough in each pen, but 6 farms (2 FS, 2 BP, and 2 MIX) also provided access to water right after the parlour exit. There were 17 farms (7 FS and 10 BP) who did not provide the minimum space per head required for water, with 6 farms (1 FS and 5 BP) providing less than 3 cm water trough length per head. For feed, 3/9 farms which provided insufficient space were FS and 6/9 were BP.

In 16 farms (6 FS, 9 BP, and 1 MIX), cows accessed clean water in clean water troughs (score 0 of 2), while 22 farms (14 FS and 8 BP) provided dirty water in clean troughs (score 1), and 23 farms (5 FS, 16 BP, and 2 MIX) provided unclean water in dirty troughs (score 2 of 2;). In one small BP farm that had 26 lactating cows in one pen the water trough was empty at the time of visit and could not be scored. Empty water troughs were observed on pens with cows inside them (these pens were outside our sample population) on 2 FS and 5 BP. Feed troughs were clean (score 0) in 22/62 farms (13 FS, 7 BP, and 2 MIX), unclean (score 1) in 31/62 (11 FS, 19 BP, and 1 MIX), and dirty in 9/62 f (1 FS and 8 BP). Feed delivery frequency was not recorded on the first 14 farms visited. Feed was delivered twice a day on 20/48 farms (1 FS, 14 BP, 1 MIX), three times per day on 23/48 (10 FS, 12 BP, 1 MIX), and for time a day on 5/48 farms (4 FS and 1 BP).

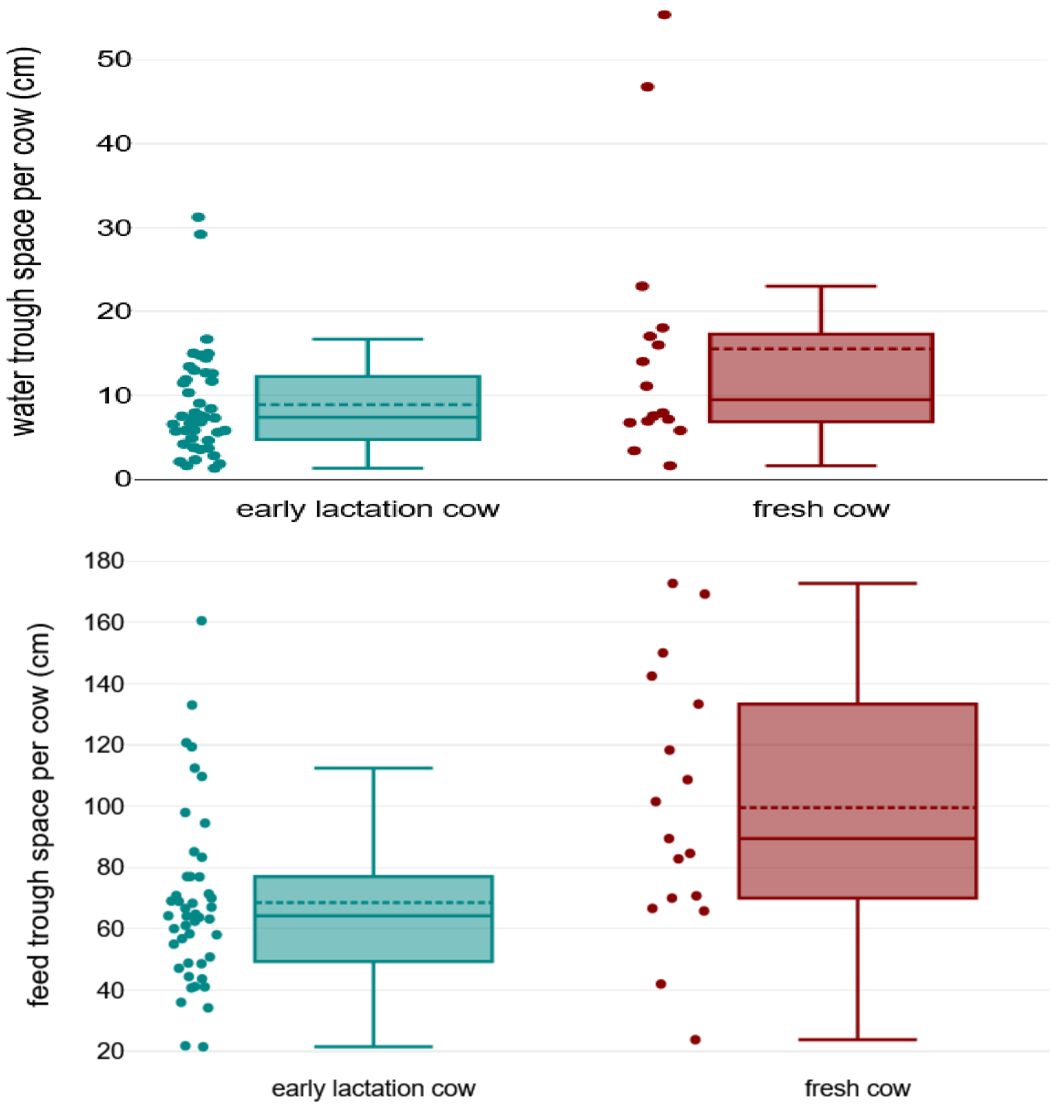

Figure 3.5. the distribution of the available feed and water trough length per early lactation and fresh cow on a study of 62 Iranian dairy farms

3. 4. 2 Cow Flow

3. 4. 2. 1 Transfer passage

Across all 62 farms, eight (all small and BP) kept cows in pens next to the parlour, so had no transfer passages. Transfer passage width and condition were recorded on 52 and 48 farms, respectively. Sharp turns, narrow gateways, and maximum walking distance were recorded in 45, 42 and 38 farms, respectively. Overall median (IQR) transfer passage width was 180 cm (120 to 300 cm; Table 3-1; Figure 3.6).

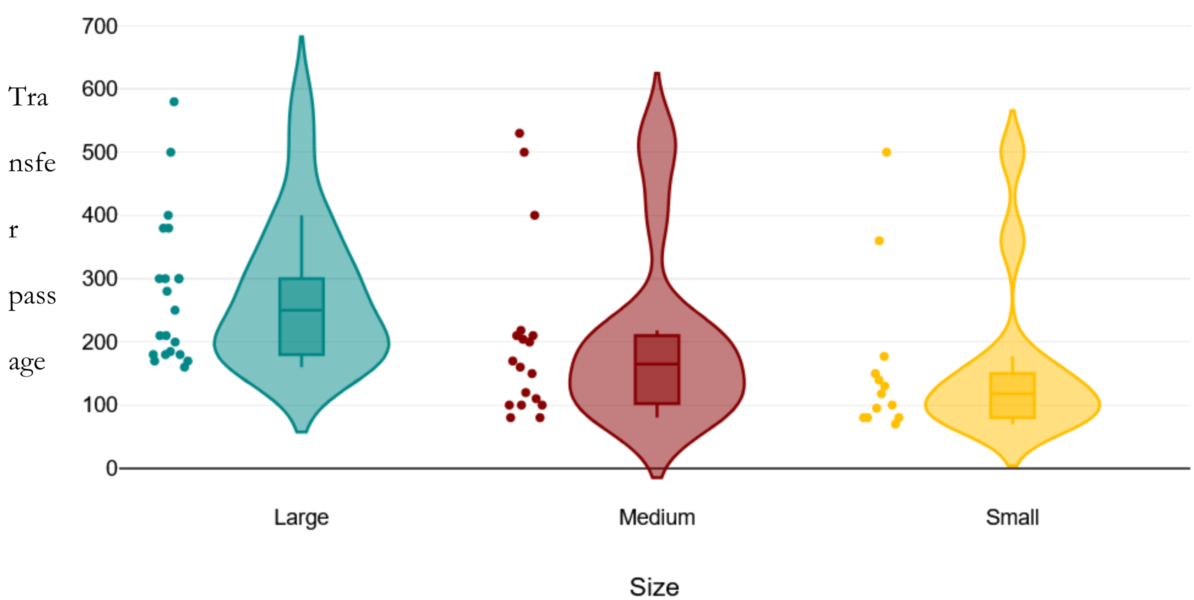

Figure 3.6. distribution of the width of the transfer passage on different farm sizes: Small: ≤180 cows; Medium: 181 to 899 cows; Large: ≥900 cows in the lactating herd

For small, medium, and large farms median (IQR) width were 118 cm (80 to 150 cm), 185 cm (105 to 214 cm), and 265 cm (180 to 340 cm), respectively. Transfer passage condition was good in 25/48 farms (16 FS and 9 BP), moderate in 8/48 (5 FS and 2 BP), and poor in 15/48 (7 FS and 8 BP). Sharp turns in the transfer passages were observed in 24/45 farms (16 FS and 8 BP), whereas narrow gateways were observed in 6/42 farms (1 FS, 4 BP, 1 MIX). The median (IQR) maximum walking distance from a pen to the parlour (one-way only) was 160 m (120 to 230 m; n=38).

3. 4. 2. 2 Milking Parlour and Holding area

Number of milkings per day and observing cows with "heads up" in the holding area were recorded on 58 farms, while return time was recorded on 54. Use of rubber mats inside parlour and in holding area was recorded on 62 farms, but the quality of surface in holding area was recorded on 56 farms. Entrance and exit slopes were recorded on 59 farms and existence of sharp turns after parlour exit on 48 farms. Noise level was recorded on 61 farms.

Cows were milked twice a day in 4 BP Farms, 3 times a day in 52 farms, and 4 times a day in one FS farm (n=57). Median (IQR) return time from each milking was 61 (50 to 80) minutes (Table 3-1) and total time away from milking ranged from 50 to 350 minutes per day (Figure 3.7). Cows were observed with "heads up" while waiting in the holding areas in 31 farms (12 FS, 16 BP, 3 MIX). The holding area and parlour surface were covered (either fully or partially) with rubber mats in 16/62 (10 FS and 6 BP) and 33/62 farms (19 FS, 13 BP, 1 MIX), respectively. Holding area surface was slippery in 1 FS farm. Median (IQR) gradients for parlour entrance and exit were 5% (3 to 8%) and 5% (3 to 10%), respectively. Two farms had an exit gradient of >25%. Overall, 41/62 of farms had an entrance and exit gradient of ≤10%. Sharp turns at parlour exit were observed on 31/48 farms. Noise levels were 0, 1, and 2 on 20, 33, and 8 farms, respectively.

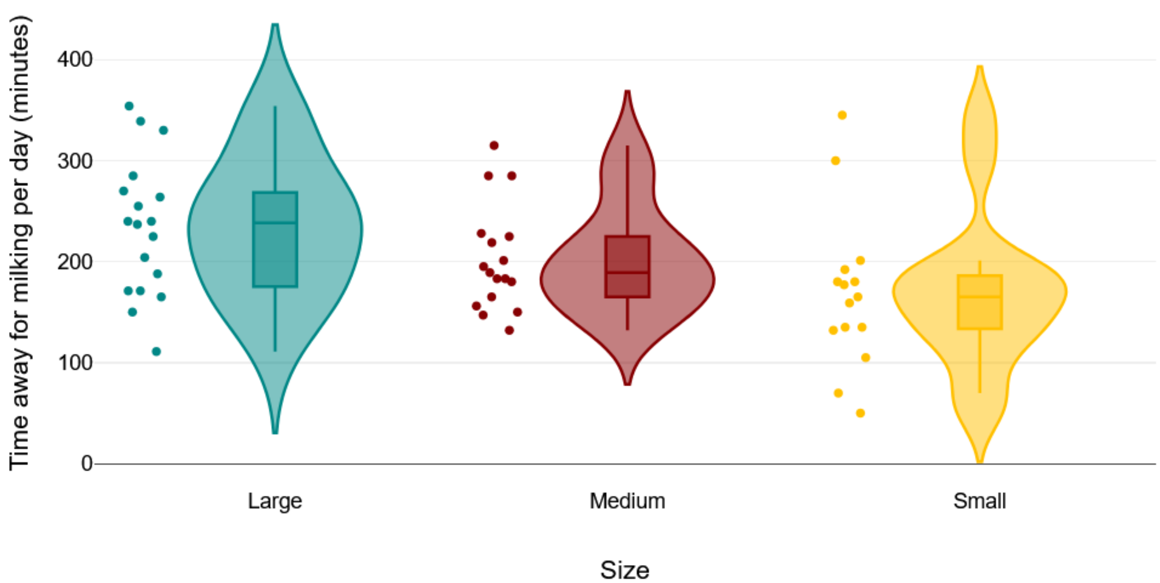

Figure 3.7. Total time away for milking per day in different farm sizes: Small: ≤180 cows; Medium: 181 to 899 cows; Large: ≥900 cows in the lactating herd

3. 4. 2 Hoof Health Management

We recorded the number of hoof trimmings per year on 56 farms (excluding the first four farms visited and two farms who could not provide the information). We recorded who did the trimming on 50 farms. Availability and frequency of footbath use, and product used were recorded from on 53 farms, with availability of a pre-wash bath on 41 farms. Functional hoof trimming was done on all but one farm (55/56). Twelve farms (9 FS and 3 BP) trimmed >2 times/year, 39 twice a year (10 FS and 28 BP, 1 MIX), and 4 <2 times a year (2 FS, 1 BP, 1 MIX). Twenty-one farms (9 FS and 11 BP) used trained staff for hoof trimming, while 29 (10 FS, 17 BP, 2 MIX) hired contract hoof trimmers (n=50). Additionally, 30/53 (16 FS, 12 BP, 2 MIX) farms had foot baths, but only 4/41 (2 FS and 2 BP) had pre-wash baths before the foot bath. Two of the 30 farms with footbaths did not use them (both BP), Of the remaining 28 farms with a footbath, 19 farms used the footbath ≥3 times a week, 4 weekly, and 5 as needed. Formaldehyde was the main solution used in the foot baths (27/28).

Table 3-1- Distribution of different resource-based welfare measures in a cross-sectional study of 62 Iranian dairy farms

Measure	Unit	Mean	95% CI for Mean Lower	95% CI for Mean Upper	First Quartile	Median	Third Quartile	Minimum	Maximum	n
Feed and water availability										
Feed space/ head early lactation cow [1]	cm	68.5	60.1	77.0	48.8	64.2	77.1	21.5	160.5	46
Feed space/ head fresh cow [2]	cm	99.6	77.4	121.7	70.0	89.5	133.3	23.8	172.7	17
water space/ head early lactation cow	cm	8.87	6.91	10.8	4.60	7.37	12.6	1.30	31.2	43
water space/ head fresh cow	cm	15.5	7.47	23.6	6.83	9.51	17.6	1.60	55.4	16
Distance to water after parlour	m	77.7	56.6	98.9	30.0	50.0	100	0	380	59
Housing in bedded-pack farms										
Bedding depth in bedded-pack farms	cm	20.3	14.7	25.9	12.5	15.0	30.0	2.0	80.0	32
Resting area/ head early lactating cow	cm^2	575	420	730	300	463	485	125	1558	25
Resting area/ head fresh cow	cm^2	784	505	1063	571	808	1042	452	1586	9
Housing in free-stall farms										
Bedding depth in freestall farms	cm	12.6	8.52	16.6	5.0	10.0	17.5	2.0	50.0	28
Stocking density in freestall farms [3]	%	98.7	86.6	110.7	85.3	95.2	121.0	33.3	139.5	21
Length- single row stalls	cm	230	214	246	215	228	240	210	275	9
Length- double row stalls	cm	247	238	256	230	255	260	205	273	21
Width	cm	116	114	118	115	116	120	105	125	24
Brisket height	cm	20.4	3.47	37.4	10.0	15.0	25.0	8.0	60.0	7
Low loop height	cm	33.3	29.2	37.3	28.0	32.0	40.0	18.0	60.0	23
Loop diameter	cm	77.0	74.4	79.6	74.0	77.0	80.0	64.0	92.0	23
Neck rail height	cm	124	121	127	116	125	130	115	135	23
Curb to brisket	cm	220	201	239	205	215	225	205	265	7
Rear curb width	cm	15.2	12.3	18.0	10.0	15.0	20.0	8.0	33.0	23
rear curb to Neck rail	cm	163	155	171	160	165	170	115	195	23
Rear curb to stall divider	cm	34.1	27.6	40.5	25.0	30.0	40.0	13.0	75.0	23

				Cow flow management						
Returning time per milking [4]	min	66.2	59.9	72.4	50.0	61.0	80.0	25.0	118	54
Milking shed entrance slope	%	6.0	4.7	7.3	3.0	5.0	8.0	0	21.0	59
Milking shed exit slope	%	6.8	5.3	8.3	3.0	5.0	10.0	0.0	25.0	59
Transfer passage width	cm	225	187	262	120	180	300	70	580	51
Maximum walking distance	m	193	153	232	120	160	230	50	560	38

1- Cows with days in milk of 22 to <150
2- Cows with days in milk of 1 to 21
3- number of cows per 100 stalls
4- Time interval between when the first cow leaves the pen and when the last cow returns to the pen

3. 4. 2 Farm Records

All farms were asked to provide their recorded incidence of mastitis, incidence of lameness, culling rate, calf mortality rate, days open (all based on yearly data), and their latest record of average milk yield per cow, milk fat percentage, milk protein percentage, milk somatic cell count (SCC), and herd average DIM. Overall, 42 farms (16 FS, 23 BP, 3 MIX) provided some data, however, only 31 farms (13 FS, 15 BP, 3 MIX) provided >50% of the data we asked for. The main reasons for not providing data were not having a reliable record (n=28/62; especially for the incidence of lameness and mastitis), not being able to access the data (e.g., the person responsible for farm records was not working on that day, or they did not keep the records; n=15/62), and being too busy; n=11/62). Median (IQR) farm recorded incidence of lameness, mastitis, and rate of calf mortality were 8.3% (6.1 to 18.0%), 14.6% (5.4 to

23.6%), and 6.1% (3.5 to 9.6%), respectively. Table 3-2 provides a full summary of farm records.

Table 3-2- Distribution of farm recorded data regarding different welfare issues and performance indicators on 62 Iranian dairy farms

Farm recorded data [1]	Unit	Mean	95% CI for mean		Q1	Median	Q3	Minimum	Maximum	N [2]
			Lower	upper						
Mastitis [3]	%	18.2	10.9	25.6	5.4	14.6	23.6	1.40	77.0	25
Lameness [4]	%	12.8	9.11	16.4	6.05	8.25	18.0	1.70	38.7	32
Culling	%	27.5	21.4	33.5	18.0	25.0	33.1	5.20	65.3	28
Calf Mortality	%	7.31	5.21	9.40	3.47	6.10	9.57	0	28.3	31
Days open	days	138.7	126.4	151.1	121.0	133.0	150.0	103.0	238.0	22
Average Milk Yield	Litre/day/cow	35.4	34.1	36.6	33.2	36.0	38.0	26.0	43.6	42
Milk Fat	%	3.51	3.42	3.61	3.40	3.50	3.70	2.70	4.00	35
Milk Protein	%	3.13	3.07	3.19	3.02	3.09	3.20	2.90	3.50	26
Milk SCC x 1000	cells/ml of milk	244.8	184.5	305.0	185.0	214.5	259.0	63.0	800.0	24
Days in milk	days	178	170	186	158	179	190	148	230	30

1- Data are for the entire herd and not the sample population
2- N represents the number of farms who provided the data
3- Incidence (i.e., total number of mastitis cases) of mastitis per annum
4- Incidence (i.e., total number of mastitis cases) of lameness per annum

3. 5 Discussion

Resource-based measures and management parameters are crucial parts of a welfare assessment protocol and are important to improve welfare, reduce risks, and make interventions [35,83]. This is the first study of welfare-related resources and records on Iranian dairy farms and thus provides a baseline for monitoring improvements and changes.

The focus of our assessment of resources was on the critical areas of housing, water and feed availability, cow flow management, and hoof health management. In all areas, we identified issues where a high proportion of farms were not providing sufficient good quality resources. In housing even though heat stress negatively affects cattle performance and wellbeing on Iranian farms [92,93], a substantial number of farms did not use cooling and ventilation systems (e.g., 30/62 farms had no fans over holding areas and 23/62 had no sprinklers). This was exacerbated by a lack of shade over feed and water troughs (28/62 farms no/partial shade) and over-crowded holding areas (31/58 farms had cows with heads-up), and a lack of resting area on BP farms (24/32 <7 m^2 and 9/32 ≤ 3 m^2). This shows a lack of understanding of the importance of heat abatement for dairy cows, especially in holding pens which are the area where cows are most prone to heat stress [94]. Furthermore, cows with insufficient shade will show more aggressive behaviour and spend more time around water troughs [95], so in such cases access to water is key to cow welfare. Our data suggest that cows on high density farms may have less access to water (*e.g.,* 4/7 farms with ≤3 m^2 shaded resting space had ≤2.5 cm/head water trough space). On such farms, cows are likely to be doubly compromised by the lack of shade.

Our data highlight that lack of heat stress abatement is an issue on many Iranian dairy farms, demonstrating the need to move from the high level, perhaps simplistic assessment, used in this study to a deeper level. For example, we did not differentiate between sprinklers, foggers, and soakers. Some farms used sprinklers and foggers over the trough and in holding areas even though it is recommended that soakers be used on such areas [94]. We need to actively measure the heat abatement ability on such farms. Similarly, we only recorded the presence/ absence of fan rather than their flow rate and their cooling effect.

For freestall housing the principal issue was around bedding depth and stall size. Bedding depth was low on many farms, with ≤10 cm on 16/28 farms and ≤5 cm on 11/28. However, it is possible that these low bedding depths could be mitigated by good stall size [96]. The median size for all stall parts in Iranian farms meets the international requirements except for stall length in single row stalls and brisket length. However, data suggest that there were a substantial number of farms that did not meet these requirements. For example, when comparing to NFA [97], the

Norwegian standard for dairy cows weighing 550 to 650 kg live body weight, 5/25 farms did not meet the stall width requirements while 6/9 single row stalls did not meet the stall length requirements.

Another issue was dirty feed alleys on 13/28 farms in this study. This issue is clearly linked to the high prevalence of dirty legs in the same farms [84] and demonstrates that further research is needed to better understand what is driving the poor cleanliness on many Iranian free stall farms, such as whether it is associated with method of cleaning.

During the study it became clear that multiple farmers thought that simply installing free-stalls could improve cow comfort and productivity without considering other changes that are needed such as the need to install fans or sprinkler/soakers and the continued maintenance costs associated with bedding. One recently converted farm had a zero percent stalls usage index, and another one had the highest prevalence of lame cows (86%) across the whole study. Clear signs of heat stress (panting and high respiratory rates) were observed on both farms.

The key housing issues on BP farms was space per cow. Across the 37 farms, available resting area ranged from <1.5 to >15 m^2, with only 11/29 farms having more than the minimum space requirement of 5.4 m^2 per cow [98]. We need more data on the factors driving the low space per cow on Iranian dairy farms and the effect of this on cow behaviour as well as productivity, especially for the latter, as current published evidence of the effect is equivocal [99-101].

For water and feed availability, trough space was insufficient on too many farms (Figure 3.5). Twenty-eight percent of farms did not provide the recommended 6 cm per cow water trough length [42], and 10% failed to provide half of the recommended space. This was exacerbated by 8/62 farms having at least one pen with no water at the time of the visit and cows not having access to clean water in more than one third of farms, which can impair cows' behaviour [102]. Research shows that this lack of access to water in dairy cattle farms is a global problem [103-105], but for our study farms it is of particular importance as all the farms were located in arid and semi-arid regions (so at high risk of heat stress) [106], and all cows were fed TMRs with high dry matter contents.

There were similar, though perhaps less severe issues with feed troughs. Space per head was less than recommended (i.e., 47 cm per cow) on 9/46 farms. Additionally, troughs were dirty on 9/62 farms, 2 of which had <47 cm feed trough length per cow. This lack of attention to trough management contrasts with our findings regarding nutrition management on these farms [84] and low number of cows with low body condition score. Further research is needed to investigate the welfare and productivity impact of poor trough management on welfare in Iranian dairy farms.

Transfer passage width ranged from 70 cm to 580 cm, and it was <130 cm on 14/52 farms. However, the width requirements vary depending on the number of cows per herd. We suggest a minimum transfer passage width of 130 cm on any farm to allow two cows to use the transfer passage at the same time and avoid congestion caused by lame or distracted cows, which might in turn encourage the stockperson to use force to move the cows. However larger herds probably need larger passages. A minimum of 500 cm [107] might be useful for large farms (>900 lactating cows in this study) where herds of >120 cows are regularly transferred through the lanes, while for medium farms (181 to 899 lactating cows in this study) a minimum of 244 cm be useful [108]. Using these standards, 2/21 large farms, 4/20 medium farms, and 5/12 small farms met the requirements (Figure 3.6). In addition, cows were deprived of a good transfer passage (i.e., score 0 in a 0 to 2 scoring system; no hazards) on 23/48 farms, while there were potential hazards (*i.e.,* scores 1 and 2 in a 0 to 2 scoring system; existence of big holes or slippery surface) in the transfer passages on 15/48 farms. Few farms (6/42) had narrow gateways, yet 24/45 farms had sharp turns in the transfer lanes. These findings show that there is potential disruption in cow flow during milking times, which may encourage the stockperson to use force to move the cows along [84]. This lack of maintenance of the transfer passages and poor passage design might also contribute to high prevalence of lameness on Iranian farms [109].

Multiple milkings per day meant that cows spent a considerable proportion of their day away from their pen for milking, with 9/54 spending 4 to 5 hours/day and 5/54 spending 5 to 6 hours (Figure 3.7). In addition, cows stood on concrete in 46/62 holding areas with only 16/62 farms using rubber mats. This long milking time combined with lack of floor mats on the holding area might lead to increased odds of lameness on the farms [110] and a change of behaviour in cows [111].

Parlour entrance was steep (*i.e.,* >10%) in 12.5% and too steep (*i.e.,* ≥15%) in 8% of farms, while exit was steep in 17.9% and too steep in 3.4% of farms. We need further data on the impact of these structural issues particularly in combination with the poor handling as we previously reported [84] can result in increased prevalence of lameness and impaired cow welfare [112-114].

Consistent with other data from Iran [115], hoof trimming was a routine procedure on most of our farms. A recent large-scale study in the UK showed that 82% of the farms performed preventive trimming with 46% solely using a contractor and 32% solely using farm staff [116]. This is comparable to our study as 29/50 farms used a contract hoof trimmer and 21/50 used farm staff. A range of trimming frequencies was observed from none to 3 times per year, but two times was the most common frequency (39/56). On the one farm which did not trim this was because he did not "believe in trimming" despite having a lameness prevalence of 86%.

However, although trimming was common, we have very little evidence of how effective it was. One particular issue is that most people trimming hooves are trained by other hoof trimmers, with no official organisation or educational provider delivering trimming courses. The high median prevalence of lameness on our study farms (33%) [84] despite the routine use of foot trimming strongly suggest that research is urgently needed on the quality of hoof trimming on Iranian dairy farms and its impact on lameness risk and whether the prevalence of lameness on Iranian farms is associated with trimming frequency on the farms.

In addition, most farms (57%) had a foot bath and used it several times a week. This is comparable to dairy farms in Minnesota where 68% of farms used foot baths [110]. That more than half the farms used a foot bath might suggest a potentially high risk of digital dermatitis infection on the farms, which is in contrast to previous reports (reported prevalence of 12% on 4 commercial farms [117]). In addition, 27/28 farms reported using formaldehyde, which is classified as a probable human carcinogen [118].

Farm records were the final area in which we evaluated our study farms. However, the main conclusion was that on most of our farms record keeping was less than optimal. This is despite on-farm computer-based recording being available in Iran since the 1980s [119], and Iranian producers of farm management programmes, regularly holding free courses for farmers and farm staff on how to use their software.

Even where there were records, the disease-specific records lacked reliability with the recorded incidence of lameness (8.3%) not matching the prevalence of lameness identified as part of the study (33%) on these farms [84], and farm records regarding the incidence of mastitis (24%) contrast with previous report by [120] identifying a 2% prevalence of clinical and 44% prevalence of subclinical mastitis on dairy farms in southern Iran. However, data regarding calf mortality or culling might be more reliable as it seems easier to record the number of dead calves or culled cows compared to the number of cows dealing with lameness or mastitis. The most reliable set of data are assumably those regarding milk production (*i.e.,* milk yield, milk fat and protein percentage, and SCC) as these data are provided by dairy companies based on tests done in their laboratories.

3. 6 Conclusion

This study assessed resource-based welfare measures in 62 Iranian intensive dairy farms located in arid and semi-arid areas. The two main farming systems used were free-stall farms (FS; with or without a walking yard) and bedded-pack farms (BP). Overall, FS farms used more fans and sprinklers in the resting area, over the troughs, and in parlour holding area. Overcrowding was more observed in BP farms as 5 out of the 6 farms that provided <3 cm of water trough space/head were BP, and a clear lack of available resting space was observed in BP farms as well. Our results show that some farmers might underestimate the importance of providing shade for the cows as more farms provided fans and sprinklers than full shade over the troughs and resting area. Additionally, cows in almost half of the studied farms were deprived of a good walking surface in the transfer passages. The resource-based measures used in this study can be can used to assess the nutrition and physical environment domains of dairy cattle welfare (based on the 5-domain model) and can be a complement to the animal-based and stockperson-based measures (subjective measures that can cover health and behavioural interaction domains) in a thorough welfare assessment protocol.

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Chapter 4

Risk factors associated with lameness and hock and knee injuries in Iranian intensive dairy cattle farms

4.1 Abstract

Both lameness and hock and knee injuries represent significant welfare and economic concerns on dairy farms. However, there is a notable lack of data from regions such as Western Asia and from certain housing systems, including bedded-pack farms. The objective of this study was therefore to utilise data collected during a welfare assessment to identify key risk factors for lameness and leg injuries on Iranian dairy farms. A generalised linear mixed model was used to identify risk factors associated with hock and knee injuries, whereas for lameness a binomial regression model was used. Lameness was associated with a range of measures, but a notable negative association was observed with the number of hoof trimmings per year (OR: 0.55 and 0.65 when comparing trimming >2 and 2 with <2 times a year), while using an external contractor increased the odds of lameness (OR: 1.71). All types of injuries of hock and knee were higher in free-stall farms compared to bedded-pack farms, but overall, the variation in the type of risk factors associated with the lesions indicates that their aetiologies may be distinct. A positive association was found between the number of cows with bad stockmanship and hock swelling (OR: 3.83) and ulcer (OR: 4.84). These findings are a baseline for further studies and highlight the need for assessments specifically targeted at identifying risk factors associated with lameness and hoc and knee injuries.

4.2 Introduction

Both lameness and injuries of tarsus and carpus (hereafter referred to as hock/knee injuries) are major health and welfare concern on dairy farms [121,122] and one of the main causes of economic loss with negative impacts on milk production, fertility and culling [121,123]. The prevalence of lameness around the world ranges between 5 to 45% with evidence of reduction in prevalence in the last 30 years [64,124], while, around the world the prevalence of tarsal injuries ranges from 12% to 81% and carpal injuries from 6% to 43% around the world [125].

The overwhelming majority of studies looking at risk factors for lameness and hock and knee injuries come from North America or Europe [125] so data from other regions such as Western Asia are limited. Furthermore, most studies have been undertaken in tie stall and/or free-stall (FS) farms so, even though bedded-pack (BP) farms (including compost bedded-packs) are one of the major housing systems used for dairy cattle [126,127], the effect of this type of housing on lameness and injuries has not been extensively investigated [125].

In Iran, dairy cows are usually housed in either open bedded-pack systems or free-stall housing (3rd Chapter). Thus, studying lameness and leg injuries on Iranian dairy farms provides an opportunity to evaluate the effect of these housing systems. In addition, despite a long history of intensive dairy cattle farming in Iran [5], there is only limited data available on the risk factors associated with these issues on any Iranian dairy system. As part of the development of a welfare assessment designed specifically for use on Iranian dairy farms we collected data on the prevalence of lameness, swelling, hair-loss and ulceration on the tarsal joints, and injuries on carpal joints alongside other animal-based welfare measures as well as management practices, farm demographics, and stockperson and resource-based welfare measures [84], 3rd chapter). The aim of this paper was therefore to use these data to identify key risk factors for lameness and leg injuries on Iranian dairy farms.

4.3 Materials and Methods

The study procedures were approved by the Animal Ethics Committee of the College of Agricultural and Natural Resources, University of Tehran (protocol code 6765D and 22/06/2022).

4.3.1 Farm and animal selection

Detailed descriptions regarding farm selection are provided in [84]. In brief, using a convenience selection of farmers followed by snowball sampling, we visited 62 intensive dairy farms in five key dairying provinces in Iran and recorded animal-based, stockperson-based, and resource-based welfare measures.

4.3.2 Scoring Systems

4.3.2.1 Outcome variables

Five outcome variables were included in this analysis i.e. prevalence of lameness, hock swelling, hock hair-loss, hock ulcer, and knee lesions. All outcome variables were assessed by a single the first author [84].

Cows were locomotion scored as they exited the parlour after milking, but individual IDs were not recorded. A 4-point scoring system was used [52], and cows with a locomotion score of ≥2 were categorised as lame. Hock swelling, hair-loss, and ulcer as well as knee lesions were recorded while the cows were in their pen. Hock injuries were recorded on both sides of the body, and hair-loss, swelling, and ulcer were scored separately using a 4-point system [2]. A cow was categorised as 'injured' if either of their hocks had a lesion score ≥2. Knee injuries were scored on both sides of the body using a 4-point system [45] with only the highest score being recorded. Scores ≥2 were considered as injured. Individual cow IDs were recorded for hock and knee injuries.

For all outcome variables, the target population was early lactation cows (days in milk <150). For all measures, except locomotion score, the number of cows sampled in the target population was based on the Welfare Quality recommendations [42]. For locomotion scoring all cows in the target population were scored.

4.3.2.2 Risk factors

Measures collected on >50 farms during the welfare assessments were eligible for inclusion in the final model for each of the five outcomes (Figure 4.1). These measures include 11 animal-based measures, 2 stockperson-based measures, 11 resource-based measures, 5 management practices, and one farm demographic (see Chapters 2 and 3 for details of how they were collected).

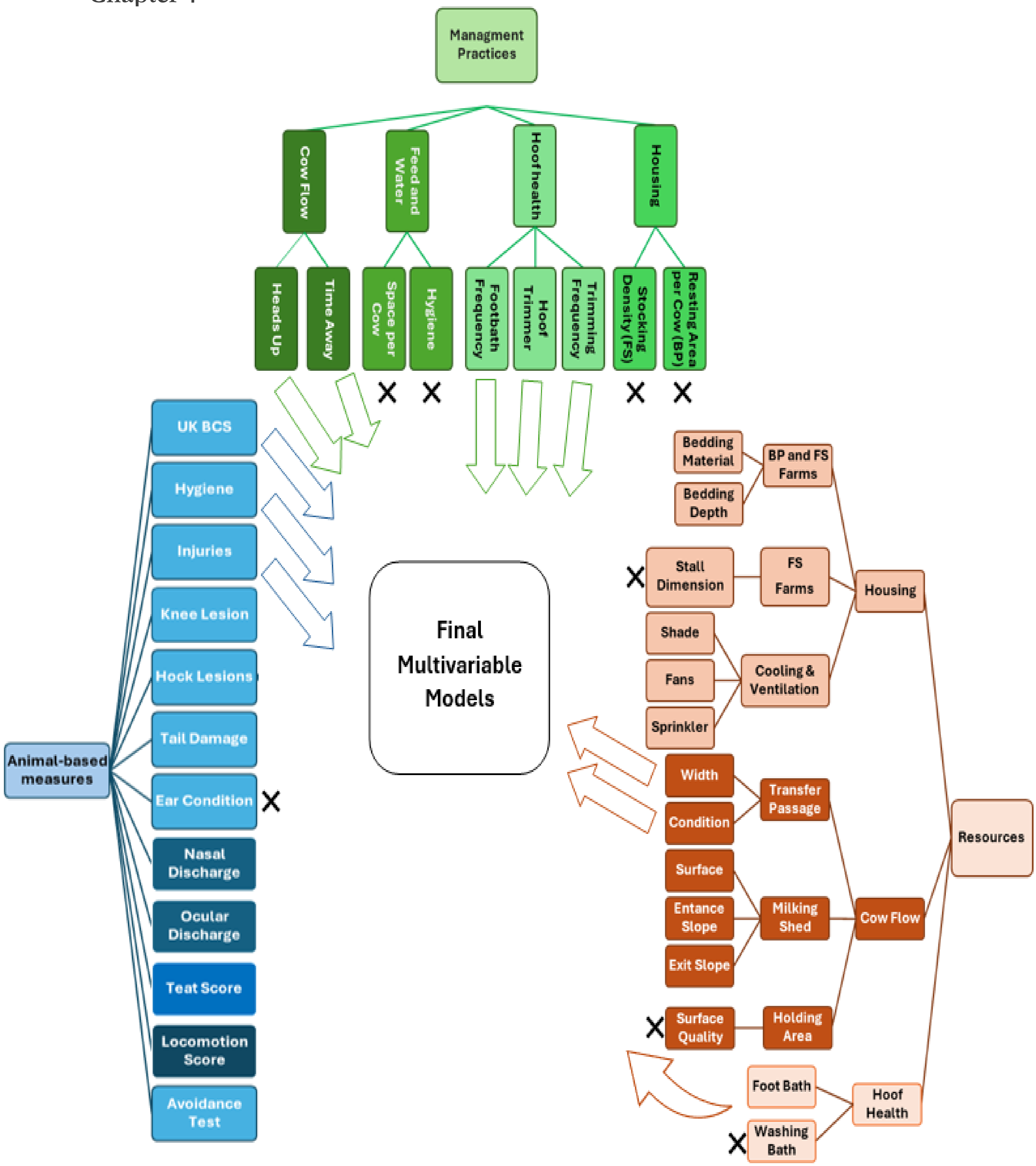

Figure 4.1. measures that were assessed in a cross-sectional study of 62 Iranian farms, and measures that were included in the final multivariable models for lameness and hock and knee injuries. Measures with an X were recorded on <50 farms and thus not selected for analysis.

4.3.3 Data handling and manipulation

Data were recorded on paper forms before being transferred to Microsoft Excel. The first author randomly checked approximately 20% of the transferred data for misrecordings or errors. Data collected at the cow-level were converted into farm-level data by calculating the prevalence of cows with a welfare problem in the corresponding category (e.g., prevalence of cows with dirty body parts in the hygiene category, or the prevalence of lame cows). This was used in multivariate analysis of risk factors associated with lameness.

4.3.4 Model selection procedure

4.3.4.1 Univariable regression models and causal diagrams

As not all measures were recorded on all farms, only the variables that were recorded on ≥50 farms were eligible for inclusion in the final models regardless of their univariable association. Causal diagrams were created [128] using previously published data (e.g., [71,129,130]) and known biological relationships between the variables to inform multivariable analyses. Additionally, each predictor variable was included in univariable binomial regression for each of the five outcome variables (i.e., lameness, hock swelling, hock hair-loss, hock ulcer, and knee injuries).

Measures that were identified in the causal diagram and showed an association with an outcome variable at $p \leq 0.40$ at univariable level were eligible for inclusion in the subsequent multivariable analyses.

4.3.4.2 Multivariable analyses

To account for multicollinearity, Spearman's rank correlation was calculated for each pair of variables. If $\varrho > 0.7$, only the variable with the lowest p-value in the univariable model was selected for the multivariable model.

For outcome variables that were recorded with individual cow IDs (i.e., hock and knee injuries), farm-level data were assigned to each individual cow from the respective farm using the "merge" function in R, and a generalised linear mixed model was used with farm identified as a random effect. For lameness, as individual IDs were not recorded, other cow-level predictors (such as back injuries) were converted to farm-level data by calculating the prevalences, and a binomial regression model was used. Therefore, for lameness all predictors were at herd-level, whereas for joint injuries there were both cow-level and herd-level predictors in the model.

Once the predictors for each of the 5 multivariable models had been identified, their variance inflation factors were calculated and if VIF > 5 in more than one variable, the variable with the highest p value in the model was eliminated. VIF was checked again until all variables had a VIF ≤5.

In all multivariable models, backward elimination was used to reduce the number of variables until all remaining variables in the model had a p-value of <0.05. If removal of a variable changed coefficients by >30%, the variable was kept in the model regardless of its p-value. Model fitness was checked using Hosmer-Lemeshow goodness of fit test.

Marginal mean prevalences were calculated for predictor variables that were included in the final models. All analyses were undertaken using R Studio 2024.12.1 Build 563.

4.4 Result

4.4.1 Data description

Predictor variables included in the final models and their scoring categories are presented in Table 4-1. Descriptive statistics of the outcome variables as well as the number of cows assessed, and number of farms visited are presented in Table 4-2.

4.4.1 Risk factors associated with lameness

Independent variables in the final multivariable model are shown in Table 4-3. These included the prevalence of cows with severe back injuries, the prevalence of cows with dirty lower legs, presence of cows with their heads up in the holding area, using external hoof trimmer rather than farm staff, the frequency of hoof trimming per year, the width of the transfer passage, the condition of the transfer passage, time away from the pen, and the frequency of footbaths. Stockperson behaviour was removed from the initial model due to high VIF (10.1).

The prevalence of lameness was positively associated with back injuries (OR: 1.56; 95%CI: 1.43 to 1.69 for every 5% increase in back injuries) and dirty lower legs (OR: 1.23; 95%CI: 1.18 to 1.29 for every 5% increase in dirty lower legs). The marginal predicted mean prevalences of lameness on farms with 5% and 10% cows with back injuries were 41.3% (36.7 to 46.0%) and 52.2% (47.2 to 57.3%), respectively. In addition, the marginal predicted mean prevalences of lameness on farms with 70% and 90% of cows with dirty lower legs were 19.0% (14.4 to 24.6%) and 35.2% (30.6 to 40.0%), respectively.

Table 4-1- Predictor variables and categories used in the regression model

	Variable	Categories used in the model
demographics	Farming system	Free-stall
		Bedded-pack
	Cows with low BCS	cows with BCS <2.5 (on a 1 to 5 scale)
		score 0: no back injuries
Animal-based	Back injuries*	score 1: moderate back injuries
		score 2: severe back injuries
	Cows with dirty lower legs	Cows with >25% dirty area on their lower legs
		Score 0: neither hitting nor using loud voices to move the cows
Stockperson	Stockperson behaviour	Score 1: using either hitting or using loud voices to move the cows
		Score 0: using both hitting and using loud voices to move the cows
	Cows with heads up in holding area	Presence of cows with their heads up
	Time away for milking	Time interval between the first cow exit and final cow re-entry to the pen
		Trimming hooves <2 times/year
Management practices	Hoof trimming frequency	Trimming hooves 2 times/year
		Trimming hooves >2 times/year
		Not using footbaths
	Foot bath frequency	More than once a week
		Less than once a week
	Transfer passage width	Width of the narrowest part of the transfer passage between pens and parlour
		Score 0 (good: no holes, bumps, or slippery surface
Resources	Transfer passage condition	Score 1 (moderate: holes with app. <10 cm diameter, uneven surface)
		Score 2 (poor: potential hazards, holes with app. >10 cm diameter, slippery surface)

Table 4-2- Distribution of the farm-level prevalence of the outcome variables across the farms

Measure	Mean	Lower 95% CI	Upper 95% CI	First Quartile	Median	Third Quartile	Minimum	Maximum	No. animals	No. farms
Lameness	35.3	31.5	39.3	26.0	32.9	42.1	8.2	85.7	14,172	61
Hock Hair-loss	38.3	31.7	44.9	17.8	36.0	51.8	0	97.9	3473	55
Hock Swelling	41.5	35.4	47.6	23.5	40.7	60.9	0	87.9	3477	55
Hock Ulcer	4.25	2.43	6.07	0	1.92	6.63	0	41.0	3474	55
Knee Injuries	28.0	21.2	34.9	6.33	16.8	46.7	0	97.4	4806	62

The prevalence of lameness was associated with both the type of hoof trimmer and frequency of hoof trimming. Using an external hoof trimmer (rather than farm staff) increased the odds of lameness (OR: 1.39; 95%CI: 1.14 to 1.68). When compared to trimming <2 times a year, trimming 2 times and >2 times per year decreased the odds of lameness by 0.61 (95%CI: 0.49 to 0.76) and 0.62 (95%CI: 0.50 to 0.78) times, respectively. The marginal predicted mean prevalences of lameness on farms that used an external trimmer and those that used farm staff were 47.0% (39.6 to 54.6%) and 39.1% (33.6 to 44.8%), respectively. Additionally, the marginal predicted mean prevalences of lameness on farms that trimmed the hooves <2 times, 2 times, and >2 times a year were 51.0% (43.5 to 58.5%), 38.9% (33.1 to 44.9%), and 39.3% (32.7 to 46.5%), respectively.

An increase of 30 minutes in the time away from the pen for milking was associated with 1.04 times (95% CI: 1.01 to 1.07) increase in the odds of lameness. The marginal predicted mean prevalences of lameness on farms whose cows spent a total of 150 minutes and 350 minutes away from the pen for milking were 40.0% (35.4 to 44.8%) and 45.6% (39.5 to 51.8%), respectively. The presence of cows with their heads up at the holding area decreased the odds of lameness by 0.68 (95%CI: 0.56 to 0.82) times. The marginal predicted mean prevalences of lameness on farms where cows held their heads up at the holding area and those that did not were 38.4% (33.3 to 43.8%) and 47.8% (40.1 to 55.6%), respectively.

The prevalence of lameness was associated with the frequency of footbath use on the farms. Compared to farms that did not utilise footbaths, those that used the footbath more than once a week had lower odds of lameness (OR: 0.58; 95%CI: 0.49 to 0.69), whereas on farms that used the footbaths less than once a week, the prevalence of lameness was associated with a range of effects from a large decrease to a moderate increase. The marginal predicted mean prevalences of lameness on farms that utilised the footbath more than once a week and those that did not use it were 35.4% (30.4 to 40.8%) and 48.4% (41.8 to 55.1%), respectively.

Table 4-3- Results of the logistic regression models to determine the risk factors associated with lameness

Predictor Variables [1]	OR (95% CI)	Predicted Means % (95%CI) [2]
Prevalence of cows with severe back injuries (10%)	1.54 (1.39- 1.71)	
2.2% cows with severe back injuries		35.4 (31.0- 40.1)
7.0% cows with severe back injuries		45.6 (40.9- 50.4)
Prevalence of cows with dirty lower legs (10%)	1.16 (1.11- 1.20)	
70% cows with dirty lower legs		19.0 (14.4- 24.6)
90% cows with dirty lower legs		35.2 (30.6- 40.0)
Absence of cows with heads up in holding area	Reference	47.8 (40.1- 55.6)
Prescence of cows with heads up in holding area	0.63 (0.52- 0.76)	38.4 (33.3- 43.8)
Using farm staff to trim hooves	Reference	39.1 (33.6- 44.8)
Using external hoof trimmer vs	1.71 (1.39-2.11)	47.0 (39.6- 54.6)
Trimming <2 times/ year	Reference	51.0 (43.5- 58.5)
Trimming 2 times/ year	0.55 (0.43-0.69)	38.9 (33.1- 44.9)
Trimming >2 times/ year	0.65 (0.52- 0.82)	39.3 (32.7- 46.5)
Transfer passage width (50 cm)	1.06 (1.00-1.12)	
120-cm wide passage		39.9 (35.0- 44.9)
300-cm wide passage		43.4 (38.2- 48.7)
Transfer passage condition: Good	Reference	44.2 (39.7- 48.9)
Transfer passage condition: Moderate	0.81 (0.54- 1.12)	38.5 (38.6- 49.5)
Transfer passage condition: Poor	1.08 (0.91- 1.28)	46.4 (39.7- 53.2)
Daily time away for milking (30 mins)	1.04 (1.01- 1.07)	
100 minutes away for milking per day		38.7 (33.7- 43.8)
300 minutes away for milking per day		44.2 (38.9- 49.7)
Not using footbaths	Reference	48.4 (41.8- 55.1)
Foot bath more than once a week vs none	0.59 (0.50- 0.70)	35.4 (30.4- 40.7)
Foot bath less than once a week vs none	0.84 (0.58- 1.22)	45.5 (35.9- 55.5)

1- Variables with a unit in front of them are continuous and others are categorical
2- Predicted means (PM) of lame cows in each predictor category if the effects of all other predictors are set to zero. For categorical variables, PM of each variable category was calculated (e.g., hoof trimming frequency) and for continuous variables (e.g., passage width) first and third quartiles were chosen to show the effect of the model. For dirty lower legs and daily time away, arbitrary numbers were chosen.

4.4.2 Risk factors associated with hock and knee injuries

Independent variables in the final models, their effect on the outcome variables, and the predicted marginal means are shown in Table 4-4. The final models for all four types of injuries included the farming system (BP versus FS), with all measures having clearly lower odds of occurring on BP farms except for hock ulcer, where our data were compatible with a range of effects from a large decrease to a biologically unimportant increase in the odds (OR: 0.32; 95%CI: 0.10 to 1.01) (Table 4-4).

All types of hock injuries were associated with the behaviour of the stockperson. Compared to not using loud voices and hitting to move cows, using both was associated with increased odds of hock swelling (OR:3.83; 95%CI: 1.59 to 9.19) and hock ulcer (OR:12.9; 95%CI: 1.75 to 94.2). For hock hair-loss our data were compatible with a range of effects from a large increase in odds to a biologically unimportant decrease (OR: 2.08; 95%CI: 0.93 to 4.66). In contrast, for all three hock lesions, the impact of using either loud voices or hitting (but not both) was unclear as our data were compatible with biologically important increases and decreases in odds (Table 4-4).

Low BCS were included in the final multivariable models for hock hair-loss, hock swelling, and knee injuries, with cows having low BCS increasing the odds of the injury in all cases. The presence of cows with their heads up in the holding area as risk factors, was associated with a reduction in the odds of hock swelling (OR: 0.53; 95%CI: 0.29 to 0.99); however for hock hair-loss and knee injuries our data were compatible with a range of effects from a moderate decrease in odds to a small increase (Table 4-4).

Back injuries were included in the final model for hock ulcer and knee injuries. Cows with moderate back injuries were associated with increased odds of both hock ulcer and knee injuries. Cows with severe back injuries had a clear association with increased odds of knee injuries (OR 1.62; 95%CI 1.16-2.35), with cows having severe back injuries having a range of effects on hock ulcer from a large decrease to a large increase (Table 4-4).

Table 4-4-Results of the logistic regression models to determine the risk factors associated with injuries of hock and knee

	Hock hair-loss		Hock swelling		Hock ulcer		Knee injuries	
	OR (95% CI)	PM[1] % (95% CI)	OR (95% CI)	PM [1] % (95% CI)	OR (95% CI)	PM [1] % (95% CI)	OR (95% CI)	PM [1] % (95% CI)
Farming System								
Free-stall farms	Ref	53.4 (42.6-63.9)	Ref	50.6 (38.9-62.2)	Ref	2.14 (0.79-5.63)	Ref	63.5 (51.9-73.8)
Bedded-pack farms	0.22 (0.13-0.39)	20.3 (14.6-27.5)	0.36 (0.20-0.66)	27.0 (19.4-36.3)	0.32 (0.10-1.01)	0.69 (0.24-2.02)	0.07 (0.04-0.14)	11.6 (7.56-17.3)
Body Condition Score								
Cows with BCS >2.5	Ref	30.9 (24.5-38.1)	Ref	34.6 (27.3-42.8)	---	---	Ref	29.9 (22.9-38.1)
Cows with BCS ≤2.5	1.46 (1.23-1.74)	39.6 (32.0-47.6)	1.35 (1.14-1.59)	41.7 (33.3-50.5)	---	---	1.25 (1.03-1.50)	37.7 (26.9-43.5)
Back Injuries								
Cows with no back injuries	---	---	---	---	Ref	1.00 (0.44-2.22)	Ref	24.8 (19.4-31.1)
Cows with moderate back injuries	---	---	---	---	2.22 (1.02-4.83)	2.18 (0.75-6.19)	1.84 (1.18-2.89)	37.8 (26.3-50.8)
Cows with severe back injuries	---	---	---	---	0.84 (0.37-1.87)	0.83 (0.27-2.51)	1.62 (1.16-2.35)	35.2 (25.7-46.1)
Cows with Heads Up								
Absence of cows holding their heads up at holding area	Ref	39.5 (30.5-49.2)	Ref	45.7 (35.5-56.3)	---	---	Ref	38.7 (28.0-50.6)
Presence of cows holding their heads up at holding area	0.69 (0.39-1.22)	31.0 (22.2-41.3)	0.53 (0.29-0.99)	31.0 (21.5-42.4)	---	---	0.57 (0.31-1.07)	26.5 (18.6-36.4)
Stockperson Behaviour								
Using neither hitting nor loud voices to transfer cows	Ref	30.0 (17.4-46.6)	Ref	24.8 (13.2-41.6)	Ref	0.39 (0.06-2.63)	---	---
Using hitting or loud voices to transfer cows	0.96 (0.39-2.37)	29.2 (19.5-41.4)	1.70 (0.64-4.52)	35.9 (23.9-50.0)	2.36 (0.26-21.11)	0.93 (0.27-3.15)	---	---
Using both hitting and loud voices to transfer cows	2.08 (0.93-4.66)	47.2 (38.4-56.2)	3.83 (1.59-9.19)	55.8 (46.0-65.1)	12.9 (1.75-94.2)	4.84 (2.30-9.92)	---	---

1- Predicted means of cows having the respective joint injury in each predictor category if the effects of all other predictors are set to zero. For example, under "Hock Hair-loss" column, the PM in "Free-stall farms" and "Bedded-pack farms" rows show the predicted mean prevalence of cows with hock hair-loss kept in free-stalls compared to cows kept in bedded-packs and assuming no other factors are influencing hock hair-loss.

4.5 Discussion:

This is the first study investigating risk factors associated with lameness and hock and knee injuries on Iranian intensive dairy cattle farms. Even though there are a few studies investigating the prevalence of lameness and different types of claw lesions on Iranian farms (e.g., [23,117]), to the best of our knowledge, there are no studies on injuries of hock and knee joints, and no studies of the risk factors associated with lameness or hock and knee injuries. This lack of data is important as it limits our ability to put in place preventive programmes to reduce the prevalence of such injuries. This study, as the first of its kind in Iran, is intended to be a starting point towards a better understanding of the risk factors for lameness and leg joint injuries on Iranian dairy farms, not an end point. It is particularly important to note that non-inclusion of a variable in the final multivariable model does not mean that that variable had no effect on the outcome, just that it did not meet the threshold for inclusion in that model. Furthermore, the risk factors included in this analysis were collected for a welfare assessment and it is quite plausible that we have not collected data on important risk factors for either lameness or leg joint injuries. As such we need more data to test some of our conclusions and provide further information on the factors driving lameness and hock/knee injuries in Iranian dairy cows.

4.5.1 Risk factors associated with lameness

The median (IQR) prevalence of lameness on the farms was 33% (26 to 42%), which is comparable to North American and European studies [131-133]. Our final model for lameness included a mixture of animal-based factors, resource-based factors, and management practices on both FS and BP farms.

Hoof trimming frequency and use of a contractor were included in the final model. Preventive trimming is frequently identified as a means of reducing lameness (e.g., [110] [132]) with increasing frequency of trimming being associated with reduced lameness prevalence [134]. This consensus has clearly influenced practice in Iran with 55 out of 56 farms using preventive trimming and 51 trimming at least twice a year. Our analysis is also consistent with trimming being a useful means of reducing lameness as we found clear evidence that trimming ≥2 times a year was associated with less lameness. However, our data suggest that trimming more than 2 times per year may not confer additional benefits in reducing lameness as the odds of lameness when trimming >2 times a year are 1.02 (95%CI: 0.74 to 1.41) times that of trimming twice a year. Further investigation is needed to validate this observation. We also found an effect of the person doing the trimming on the odds of lameness with farms who used a contractor having a much higher prevalence of lameness than those who used farm staff (marginal mean 47.0 vs 39.1%, respectively). We need more data to confirm whether this difference reflects the true situation and, if it does, what is driving it. Normally it is considered that having trained hoof trimmers (who are usually outside contractors) is beneficial for lameness [134] so the effect we identified in this study is unexpected. However, there are two potential reasons for this unexpected effect. Firstly, farms may be more likely to use external contractors when they have a lameness problem (i.e. it is lameness prevalence that is affecting the use of contractors rather than the other way around), and secondly, the external contractors on farms included in this study were not well-trained (or at least some of them were not). Both of these reasons could be acting together: farms employing poorly trained contractors because they have a lameness problem. There is currently no official hoof trimmer training program in Iran and no organisation to overlook the practice and knowledge of the trimmers. We need to urgently evaluate how well trimming is undertaken on Iranian dairy farms and work to improve outcomes from both contractors and farmers.

The presence of cows with their heads up in holding area is commonly used in New Zealand a farm-level quantitative indicator of overstocking in the collecting yard, and with improper handling and continuous pushing of cows (as observed in the current study) contributes to excessive stocking density in the holding [135]. Ranjbar et al. [136] found that on farms with no cows with their heads up, cows had decreased odds of lameness (OR: 0.57; 95%CI: 0.55 to 0.84). However, in this study, we found the opposite as farms with overstocked holding areas had lower odds of lameness (predicted marginal mean prevalences of lameness of 38.4% and 47.8%, on farms with heads up and those without, respectively). Further investigation is needed to validate these findings.

The effect of footbaths on the prevalence of lameness is still a matter of debate, with some studies reporting beneficial effects (e.g., [137]) and some reporting detrimental effects on lameness (e.g., [138]). However, these studies mostly investigated the presence/ absence of footbaths. In our study, nine out of 30 farms equipped with footbaths either did not utilise them or did so infrequently. This suggests that simply recording the presence of footbaths may yield misleading conclusions, as it does not account for actual usage patterns. As far as we are aware, no other studies have investigated the effect of footbath frequency on lameness except for Griffiths et al. [132] who reported that using the footbaths between 2 and 6 times a week reduced the risk of lameness compared to using the footbaths once or >6 times a week, and Espejo and Endres [110] who investigated the effects of using footbath ≥2 times a week compared to <2 times time and not using it and were not able to find an association between frequency of footbath and lameness at univariable level. In our study, using a footbath more than once a week was associated with decreased odds of lameness. We need more data on the use of footbaths in the two farming systems (FS and BP farms), the volume per cow, frequency of changing, concentration of the footbath material (mostly formaldehyde in this study), and prevalence of digital dermatitis on Iranian farms.

Time away from the pen is an important welfare measure that can influence the time budget of cows [139]. Increasing the time spent on milking will negatively influence other essential activities such as feeding and lying times [139] and increase the odds of lameness [110]. In our study cows spent a median of 3.2 hours (interquartile range: 2.75 to 4.25 hours) away from the pen for milking. Our multivariable model showed that each 30 minutes increase in the time away from pen increased the odds of lameness by 1.04 (95%CI: 1.01 to 1.07) times. Time away from the pen was not influenced by farm size (e.g., median IQR time away in small and large farms was 177 minutes (135 to 192 minutes) and 240 minutes (188 to 280 minutes), respectively). Therefore, cows in all farm sizes were prone to prolonged times away from their pens. Further research is needed to see how the time budget of Iranian cows is affected by long milking times and identify whether it is these changes in time budget which are responsible for the increase in lameness.

Other factors included in our final models included back injuries, dirty body parts, and width and condition of the transfer passage. As far as we are aware these risk factors have not been identified as risk factors for lameness in previous studies [125]. This may reflect lack of inclusion in previous studies (e.g. back injuries) but may also reflect that these factors are potentially proxies for other factors which are commonly included in studies of lameness risk factors (e.g. back injuries in FS farms may reflect stall design).

4.5.2 Risk factors associated with hock and knee injuries

The median (IQR) prevalence of hock and knee injuries in the farms ranged from 1.92% (0 to 6.63%) for hock ulcer to 40.7% (23.5 to 60.9%) for hock swelling. Overall, FS farms exhibited a higher prevalence of hock and knee injuries. This aligns with a previous study reporting that cows transitioning from FS to BP experienced a significantly higher healing rate for injuries of tarsus and carpus (OR: 2.2; 95%CI: 1.14 to 3.44) [140].

Although it has been proposed that hock swelling follows hock ulcer, which in turn follows hock hair-loss [122], our findings suggest a different pattern. The variation in the type of risk factors associated with the lesions indicates that their aetiologies may be distinct. Among the five predictor variables that remained in the final models for risk factors associated with hock injuries, only 2 were shared between all the lesions: farming system (bedded-pack versus free-stall farms) and the stockperson behaviour. Similarly, Potterton et al. [142] and Lim et al. [143] suggested that different hock lesions may have different aetiologies. Our data also support the idea that the underlying causes and mechanisms of development for knee and hock injuries are likely distinct [129].

Hock and knee injuries were associated with two cow level measures, i.e. BCS and back injuries. Cows with low BCS were associated with higher odds of hock hair-loss and swelling and knee injuries. Similarly, previous studies have reported higher odds of hock injuries in cows with low BCS [143,144]. Nash et al. [144] hypothesised that a thinner fat pad around the hock in low BCS cows increases the risk of hock injuries in these cows despite the fact that there is no fat pad around the hock [145]. We hypothesise that the interaction between cows with low BCS and cows with hock and knee injuries might be related to lameness [143], however, due to the absence of individual cow identification during locomotion scoring, it was not possible to investigate this relationship at the individual cow level within the constraints of our dataset. Further research is warranted to validate this hypothesis.

In addition, moderate injuries on the back were associated with increased odds of hock ulcer, while knee injuries were positively associated with both moderate and severe back injuries. There is a lack of data regarding the association between back injuries and hock and knee lesions. However, injuries on the back are associated with a range of environmental variables including stall design and dimensions. Further research is required to investigate how back injuries are related to hock and knee injuries and whether this varies between the farming systems.

Presence of cows with their heads up in the holding area was associated with reduced odds of hock swelling in our study. Previous studies have not reported this measure as a risk factor for tarsal or carpal injuries, but other density -related measures have been investigated as predictors of these lesions and have reported a positive association between overstocking and prevalence of the lesions. We need more data to investigate the effects of overstocking on hock and knee injuries on Iranian farms. For example, a previous study reported that odds of knee injuries increased by 2.69 (95% CI: 1.28 to 5.64) times on farms where cows slipped or fell at the parlour holding area [129], a measure that was not recorded in our study. We observed an increased odds of hock swelling and ulcer on farms that used both hitting and loud voices to move the cows (OR: 3.83; 95% CI:1.59 to 9.19 for swelling and OR: 12.9; 95% CI:1.75 to 94.2 for ulcer) indicate the importance of good stockmanship in improving cattle welfare and reducing injuries.

4.6 Conclusion

This is the first study to report the risk factors associated with lameness and injuries of tarsus and carpus and is intended to serve as baseline data for further research. We identified several animal-, resource-, management-, and stockperson-based risk factors. Farming system influenced all injuries of tarsus and carpus, with bedded-pack farms having lower odds of injuries. Hock hair loss and hock swelling shared common risk factors, although the magnitude of their effects differed slightly. Lameness, along with hock and knee injuries, shared two risk factors that had similarly significant impacts. Our conclusions are based on a single cross-sectional assessment rather than multiple assessments over time and predictor variables were identified from a welfare assessment protocol designed for a broad investigation of dairy cattle welfare rather than from an assessment specifically targeted at identifying risk factors associated with lameness and injuries of tarsus and carpus. In addition, we did not identify individual lame cows, so our analysis on risk factors associated with lameness was based on only farm-level predictors rather than animal-level ones.

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Name and title of main supervisor:	Professor Richard Laven		
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Chapter 5

Risk factors associated with broken tails on Iranian dairy cattle farms

5.1 Abstract

Unlike lameness and mastitis which have direct financial implications on farms, welfare issues with less obvious immediate economic impact, such as tail damage, have received little attention. For example, the optimal site for observing tail damage in housed cows has not yet been established. In-pen scoring is perhaps easiest but is slow and time consuming; in contrast scoring of cows as they leave the milking parlour is more rapid but probably less accurate. Thus, during a study in which we collected welfare data on Iranian dairy farms we collected tail damage data in-pen and after milking and compared the prevalence of tail damage identified by the two methods using Bland Altman's limit of agreement. In addition, we used the welfare data collected at the same time as the tail damage data to identify the risk factors for "broken tails", i.e. tails with deviation or swelling at the intervertebral space. Finally on 25 farms, farmers were asked for their estimate of broken tail prevalence, and this was compared to the prevalence estimated by in-pen tail scoring. The median (interquartile range) prevalence of broken tails using observation inside the pen and at parlour exit were similar at 51.9% (39.4 to 71.6%) and 46.6% (38.4 to 60.9%), respectively. However, there was a poor level of agreement between the two prevalences with the limits of agreement indicating that the difference between the two prevalences could be >15% across the whole range of prevalences recorded in

this study. Twelve predictors were identified as plausible risk factors for broken tails and included in a generalised linear mixed model. A positive association with broken tails was observed for trimming hooves >2 times a year (OR: 4.87; 95%CI: 1.22 to 19.4 when compared to trimming <2 times a year) and water trough length per cow (OR 1.21; 95%CI: 1.02 to 1.44 for every 2.5 cm), while transfer passage width showed a negative association (OR 0.82; 95%CI: 0.68 to 0.98 for every 50 cm). Farmer estimates of the prevalence of broken tails ranged from 0% to 10% which was markedly different from the recorded range of broken tails on those farms (6.7 to 97.4%). There was little evidence of any strong association between a farmers' estimate of broken tail prevalence and the prevalence as determined by in-pen scoring (OR: 0.87; 95%CI: 0.73 to 1.04). This study has demonstrated that parlour exit scoring cannot be used to replace in-pen scoring. However further studies are required to compare observation with observation and palpation. The risk factor study supports the idea that improper animal handling might be the leading cause of broken tails on Iranian dairy farms, and that farmer education is urgently needed to reduce the prevalence.

5.2 Introduction

Dairy cattle welfare is a major concern for both the public and the dairy industry [146,147]. In the published literature much of the focus on welfare has been on those aspects of welfare that are of major financial importance on-farm such as mastitis, lameness and body condition (e.g. Silva, et al. [148]), but areas with less obvious financial implications such as tail damage have received less attention.

Damage to the tail can not only disrupt its function but also cause a great deal of pain and distress to the cow [149,150]. Tail docking (or shortening) has long been used as a means of "controlling" parlour hygiene and improving milking staff comfort, especially in New Zealand [151] despite resulting in significant long-term pain and having limited benefits for hygiene [152]. However, the first report on the prevalence of tail damage in dairy cows other than docking only goes back to 2005 [153]. That study was a study of the impact of tie-stall design on lameness, injury, and cleanliness. Eight animal-based parameters were collected based on the opinion of an expert group, one of which the authors referred to as "broken tail", defined as a tail that had a "deviation in the vertebrae from a previous or recent break". However, although that study has been frequently cited, the principal focus of those citations has been lameness and injuries other than tail damage. For example, in their review of the impact of chain length and stall width on "common outcome measures of dairy cow welfare" in cows in tie stalls, Boyer and Vasseur do not even mention tail damage [154]. This lack of interest in tail damage is also reflected in welfare assessment programmes which either do not routinely include the proportion of broken tails as an assessment or just mention it in passing [155].

Given this apparent lack of interest in tail damage, it is perhaps unsurprising that there are very few studies of risk factors associated with tail damage in housed dairy cows [50,156], and also, as far as the authors are aware, no published studies on the best approach to detect tail damage. As part of an assessment of welfare on Iranian dairy farms [84], we recorded tail damage prevalence at two sites (in-pen and walking back to the pen after milking) alongside a range of animal-based, stockperson-based and resource-based welfare measures. The aim of this paper is therefore to assess the agreement of the prevalence results in the two sites and to conduct a risk factor analysis using the welfare measures collected alongside tail damage prevalence to identify the factors associated tail damage in housed dairy cows.

5.3 Materials and Methods

The Animal Ethics Committee of the College of Agricultural and Natural Resources, University of Tehran, approved all procedures used in this research (protocol code 6765D and 22/06/2022).

5.3.1 Farm and animal selection

Farm selection is described in full in Jafari-Gh. et al. [84]. In brief, we aimed to visit a minimum of 60 intensive dairy farms in five key dairying regions of Iran. After an initial convenience selection of two farms, snowball sampling was used to reach the target. Farm visits started in May 2022 and ended in March 2023 with 62 farms having been visited.

Initially the whole lactating herd was chosen as the target population, and the recommendation by Cook [45] was used to determine sample size. However, the high number of cattle required to meet these recommendations meant that, particularly on larger farms, data collection was prolonged and not feasible. Therefore, the target population was changed to early lactation cows only (i.e., days in milk <150) and sample size was calculated based on Welfare Quality [42] assuming an expected true prevalence of 50% and 95% confidence with a precision of 15%.

5.3.2 Data collection

5.3.2.1 Tail scoring system and calibration

A modified version of the NZVA tail score [48] was used (Figure 5.1). Tail damage was recorded as broken (swelling of intervertebral space without obvious skin damage, was included alongside tail deviations in this category), shortened tail, and trauma (i.e. all tail damage that was not included in broken or shortened). The research team spent 3 months (from February to April 2023) at the University of Tehran Research Farm in Karaj, testing the assessment protocol and learning the scoring system. Videos were captured from cows with different tail conditions (i.e., normal and damaged) and scores sent to R.A.L, who had significant experience using the scoring system. The scores were checked and discussed online to reach a common understanding of the scoring system.

Tail damage was visually assessed inside the pen at feeding time using a systematic selection of the cows [84]. Sampling was restricted to cows that were standing in the feed alley (on free-stall farms) or in the walking area (on bedded-pack farms). Cows that were lying down were not scored. For free stall farms, the feed alley in the pen was mentally divided into three sections and the number of cows for sampling in each section calculated by dividing the required sample size (N) by 3 (e.g., on a FS farm with a sample size of 60, 20 cows were scored in each of the 3 sections). Within each section, sampling began with the cow closest to the starting point, and every second cow was assessed until the target number was reached. For bedded-pack farms, the process was the same except that the walking area was divided into 4 sections. A second observer stood outside the milking parlour next to a flat area of the transfer passage and visually scored tails of all cows exited the parlour after milking. The scoring system used was the same as the in-pen scoring (as in Figure 5.1). As breakage constituted for >90% of all types of damage, only broken tails were considered for further analyses.

5.3.3 Assessment of agreement between in-pen and outside of parlour tail scoring

Measurement of agreement between the two measures of tail breakage prevalence were calculated as per [157,158]. The means of the two scores on each farm were calculated and were plotted against the difference of the two scores (recorded in pen prevalence - recorded parlour exit prevalence). The assessment used linear regression to determine whether mean and difference were associated using linear regression and, if there was an association, whether variance and mean were associated ($p < 0.05$ for both). The limits of agreement were then calculated as recommended by Bland an Altman 1999 [157]. R Studio 2024.12.1 Build 563 was utilised to undertake this analysis.

Type of damage

B: Deviation and Swelling that was not associated with skin damage

S: Shortened

T: Any visible damage to the skin (damage other than B and S)

Zones

1: Upper third

2: Middle third

3: Lower third

Figure 5.1. scoring system used to record different types of tail damage during a cross-sectional welfare assessment study on 62 Iranian farms

5.3.4 Assessment of welfare measures used as predictor variables

The 12 variables included in the model and their method of collection are shown in Table 5-1. The outcome variable (in-pen broken tails) and back injuries were recorded at the individual cow-level with cow IDs. However, as individual IDs for cows with high avoidance distance could not be recorded, avoidance distance data were converted into a farm-level variables by calculating prevalences. All other measures were recorded at the farm-level. Farm level data were linked to individual cows from their respective farms using the "merge" function in R.

A generalised linear mixed model (GLMM) was employed with all the variables in Table 5-1 included as predictor variables and farm specified as a random effect to account for clustering within farms. Variance inflation factor (VIF) was calculated to check for collinearity with VIF >5 as threshold for removing the variable. No elimination process was used. Model fitness was examined using Hosmer-Lemeshow test [159].

Table 5-1- Risk factors associated with broken tails and their scoring methods in a cross-sectional welfare assessment of 62 Iranian dairy cattle farms

	Variable	Categories used in the model
demographics	Farming system	Free-stall Bedded-pack
Animal-based	Cows with high avoidance	cows with an avoidance distance of >1 metre
	Back injuries	score 0: no back injuries score 1: moderate back injuries score 2: severe back injuries
Stockperson	Stockperson behaviour	Score 0: neither hitting nor using loud voices to move the cows Score 1: using either hitting or using loud voices to move the cows Score 0: using both hitting and using loud voices to move the cows
Management practices	Cows with heads up in holding area	Presence of cows with their heads up
	Time away for milking	Time interval between the first cow exit and final cow re-entry to the pen
	Hoof trimming frequency	Trimming hooves <2 times/year Trimming hooves 2 times/year Trimming hooves >2 times/year
	Noise level inside parlour	level 0 if speech between 2 people was easily heard from a 2-metre distance level 1 if speech between 2 people was heard with difficulty from 2 metres level 2 if from a 2-metre distance not heard at all from 2 metres
Resources	Trough length per cow	Length of the accessible part of water and feed troughs
	Transfer passage width	Width of the narrowest part of the transfer passage between pens and parlour
	Sharp turns in passage	Presence/ absence of turns with >90 degree and <3 m width in the transfer passage

Odds ratios (OR) were checked for clinically important associations with broken tails. As the average prevalence of cows with broken tails was 55.4%, on the average farm, changing the category of risk factor with an odds ratio of 0.82 or 1.18 would result in a 10% decrease/increase in prevalence. These OR were therefore used as the thresholds for determining whether the impact of a categorical risk factor was clinically important. For continuous predictors, if the CI of the OR form the model excluded both 0.82 and 1.18, the OR were recalculated using a plausible change in that variable to identify whether the OR thresholds were still excluded. For example, if a 5 cm change in a variable had an OR whose CI excluded 0.82 and 1.18, but a 12 cm change was a plausible change the OR was recalculated for the 10 cm change and the thresholds compared to the CI of that OR. As farmers' estimates were collected on only 25 farms, they did not meet the model inclusion criteria and thus were only analysed on a univariable level. R Studio 2024.12.1 Build 563 was utilised to undertake data analysis.

5.3 Result

Table 5-2 shows the descriptive data for the estimated prevalence of broken tails from the two sites as for the continuous variables used in the risk factor model and farmer estimates of the prevalence of broken tail on their farms. In-pen and post milking tail damage data were collected on 61 and 62 farms, respectively. Across all 61 farms, the median (interquartile range; IQR) in-pen prevalence of broken tails was 51.9% (39.4 to 71.6%), with the median (IQR) prevalence of shortened tails being 3.45% (1.49 to 6.45%) and that of tails with trauma being 1.82% (1.00 to 4.29%).

Table 5-2 distribution of continuous measures assessed in a cross-sectional study of 62 intensive Iranian farms. These measures were used to create a risk factor model for broken tails on these farms

	variables	Mean	Lower CI	Upper CI	Q1	Median	Q3	Minimum	Maximum	Animals scored	No. farms
Animal-based	Prevalence of cows with broken tails (in pen) [1]	55.4	50.1	60.8	39.4	51.9	71.6	6.67	97.4	4,796	61
	Prevalence of cows with broken tails (parlour exit) [1, 2]	50.1	45.7	54.5	38.4	46.6	60.9	17.6	92.2	10,271	62
	Prevalence of cows with a high avoidance distance	36.1	31.7	40.5	21.1	36.4	46.6	3.70	70.4	4,404	60
	Prevalence of cows with severe back injuries	5.64	4.24	7.05	2.20	4.30	7.02	0	31.1	4,805	62
Resource-based	Feed trough length per cow (cm)	68.5	60.1	77.0	48.8	64.2	77.1	21.5	161	---	46
	Water trough length per cow (cm)	8.87	6.91	10.8	4.60	7.37	12.6	1.30	31.2	---	43
	Daily time away for milking (min) [3]	209	190	229	165	192	255	70	354	---	47
	Width of the transfer passage (cm)	225	187	262	120	180	300	70	580	---	51
	Farmers' estimation on the prevalence of broken tails (%) [4]	2.4	0.9	3.9	0.6	2.0	4.8	0	10	---	25

1- Observation was used to score tail breakage at both locations
2- This variable was not used in the multivariable model as the accuracy of the scoring method was found to be weak compared to observation inside the pen
3- Time from when the first cow left the pen until the last cow returned to the pen multiplied by the number of milkings per day
4- farmers' estimate on the prevalence of broken tails was not included in the multivariable model due to lack of data

5.3.1 Comparing the scoring methods

For the comparison analysis, data were included only from farms where both in-pen and parlour exit were collected. The mean (95% CI) prevalence of broken tails using observation inside the pen versus at parlour exit was 55.4% (50.1 to 60.8%) versus 50.1% (45.7 to 54.5%), respectively. There was a clear association between mean of the two results and their difference (Difference = -0.236 Mean + 6.45) (see Fig 5.2). However, data were consistent with no association between the variance and mean ($p>0.05$), so limits of agreement were calculated using the standard deviation of the difference between the two prevalences, with the 95% limits of agreement being the calculated regression line ± 1.96 * standard deviation. This resulted in the equation for the upper limits of agreement being "Upper limit = -0.236 Mean + 30.6" and that for the lower limits of agreement being "Lower limit = -0.236 Mean -17.7" (see Fig 5.2). Based on those limits of agreement, if the mean of the two scores was 30%, the model predicts that 95% of the differences between the two scores will be between -24.8% and +23.5% of that mean, while if the mean of the two scores is 70%, 95% of the differences between the two scores will be between -34.2% and +14.1%.

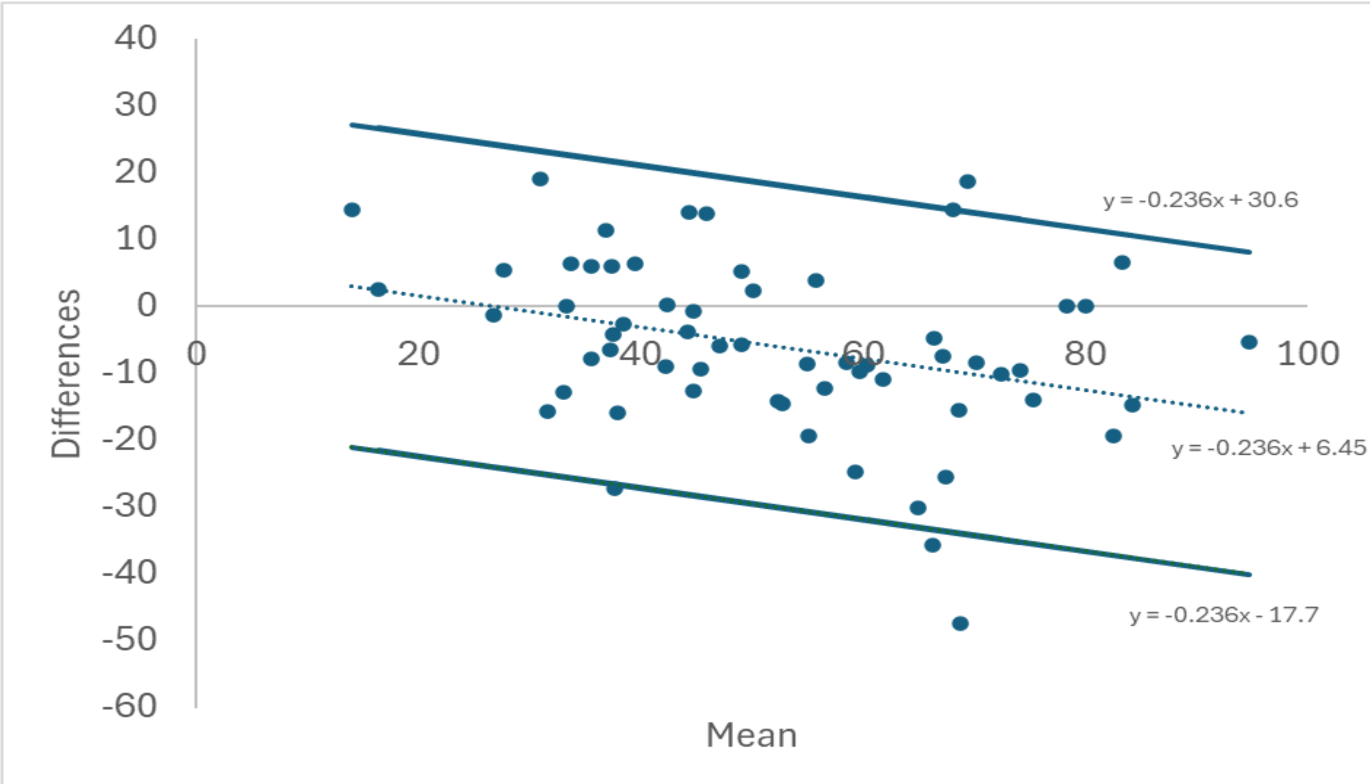

Figure 5.2. Bland and Altman limits of agreement between recording broken tails by observation inside the pen and at parlour exit. Mean is the mean of the two observed prevalences while the difference is in-pen prevalence – parlour exit prevalence.

5.3.2 Risk factors associated with tail breakage

The results of the multivariate model are presented in Table 5-3. The prevalence of cows with broken tails was positively associated with trimming >2 times per year (OR: 4.87; 95%CI: 1.22 to 19.4 when compared to <2 times per year). The effect of trimming 2 times per year rather than <2 times per year was less clear. Our data were compatible with trimming 2 times a year rather than <2 times producing a large decrease in the odds of a cow having a broken tail and a large increase (OR: 1.27; 95%CI: 0.35 to 4.59). Predicted marginal mean prevalences of cows with broken tails on farms that trimmed the hooves <2 times a year, 2 times a year, and >2 times a year were 59.5% (23.4 to 87.5%), 65.1% (42.5 to 82.4%), and 87.7% (65.9 to 96.4%), respectively (Table 5-3).

A negative association was found between the number of cows with broken tails and the width of the transfer passage as every 50 cm increase in the width of the passage was associated with a 0.82 (95%CI: 0.68 to 0.98) times decrease in the odds of broken tails. Predicted marginal prevalences of broken tails on farms with 120 cm- and 300 cm-wide transfer passages were 70.9% (53.7 to 83.6%) and 54.1% (38.8 to 68.7%), respectively (Table 5-3). Water trough space per cow was positively associated with the odds of broken tails (OR: 1.21; 95%CI: 1.02 to 1.44 for every 2.5 cm increase in trough length). Predicted marginal mean prevalences of cows with broken tails on farms with 4.6 cm and 12.6 cm water trough length per cow were 53.6% (39.0 to 67.6%) and 68.2% (51.5 to 81.2%), respectively (Table 5-3).

For the other variables, both categorical and continuous, our data did not provide clear evidence of their likely impact on the odds of broken tails as all had CI that included one or both of our clinically important thresholds (i.e. a 95% CI of <0.82 and >1.18) (see Table 5-3). Thus, for all remaining variables, our data were compatible with both no clinically important effect and a clinically important one. For example, prevalence of cows with high avoidance distance was associated with a range of effects from a clinically important reduction in odds to a small and probably clinically unimportant increase (OR: 0.81; 95%CI: 0.60 to 1.10), while our data around the effect of an increase in the average food trough space per cow of 10 cm were compatible with a range of effects from a small decrease in the odds of broken tails to a large and clinically important increase (OR 1.11; 95%CI 0.93 to 1.32). If we increase the unit from 10 cm to 28.3 cm (the difference between the lower and the upper quartile), the CI get even wider and go from a clinically important decrease to a clinically important increase (OR1.34; 95%CI 0.81 to 2.19) (Table 5-3).

The unadjusted odds of broken tails given farmer estimates showed that our data were compatible with a range of effects from a clinically important reduction to a small (and clinically unimportant) increase in the odds of a broken tail for every percent increase in farmers' estimate (OR: 0.87; 95%CI: 0.73 to 1.04). The model predicted that for farmers who estimated that 0.6% of their herd had broken tails their mean in-pen prevalence would be 56.0% (95%CI 43.1 to 68.2%), while for farmers who estimated that they had 4.8% of their cows with broken tails mean in pen prevalence would be 41.7% (95%CI 28.5 to 56.1%).

Table 5-3- Results of the logistic regression model to identify risk factors associated with broken tails on a cross-sectional study of 62 Iranian dairy farms

Predictor Variables	Odds ratio (95%CI)	Predicted means (%) [1] (95%CI)
	Categorical Variables	
Farming system		
Free-stall	---	67.6 (37.5- 87.9)
Bedded-pack	1.67 (0.64-4.32)	77.6 (53.2- 91.4)
Trimming frequency		
2 times a year	---	59.5 (23.4-87.5)
<2 times a year	1.27 (0.35-4.59)	65.1 (42.5-82.4)
>2 times a year	**4.87** [2] **(1.22-19.4)**	87.7 (65.9-96.4)
Parlour noise level [3]		
Score 0	---	72.9 (46.9- 89.1)
Score 1	1.30 (0.54-3.11)	77.7 (53.3- 91.4)
Score 2	0.78 (0.20-3.00)	67.6 (30.4- 90.9)
Presence of sharp turns in passage		
No	---	69.1 (42.0- 87.4)
Yes	1.45 (0.61-3.46)	76.4 (49.3- 91.5)
Presence of cows with heads up in holding area [4]		
No	---	69.7 (46.4- 86.0)
Yes	1.37 (0.51-3.69)	75.9 (44.4- 92.6)
Cows with back injuries		
No injuries	---	69.4 (44.3- 86.9)
Moderate injuries	1.14 (0.66-1.95)	72.4 (44.6- 89.5)
Severe injuries	1.40 (0.85-2.31)	76.4 (50.2- 91.2)

Stockperson behaviour		
Using neither hitting nor loud voices to transfer cows	---	82.0 (41.8- 96.7)
Using hitting or loud voices to transfer cows	0.31 (0.06-1.65)	59.0 (37.9- 77.2)
Using both hitting and loud voices to transfer cows	0.65 (0.19-2.27)	74.9 (51.4- 89.3)
Continuous Variables		
Daily time away for milking (30 mins)	1.00 (0.79-1.27)	
165 minutes away for milking per day		61.4 (44.7- 75.7)
255 minutes away for milking per day		61.7 (44.5- 76.4)
Width of the transfer passage (50 cm)	**0.82** [2] **(0.68-0.98)**	
120-cm-wide passage		70.9 (53.7- 86.6)
300-cm-wide passage		54.1 (38.8- 64.7)
Water trough length per cow (2.5 cm)	**1.21** [2] **(1.02-1.44)**	
4.6 cm length per cow		53.6 (39.0- 67.6)
12.6 cm length per cow		68.2 (51.5- 81.2)
Feed trough length per cow (10cm)	1.11 (0.93-1.32)	
48.8 cm accessible length per cow		58.3 (43.0- 72.1)
77.1 cm accessible length per cow		65.1 (49.0- 78.4)
Prevalence of cows with high avoidance (10%)	0.81 (0.60-1.10)	
21.1% cows with high avoidance distance		68.9 (50.4- 82.9)
46.6% cows with high avoidance distance		56.6 (40.6- 71.2)

1- Predicted means (PM) of cows having brokens in each predictor category if the effects of all other predictors are set to zero. For categorical variables, PM of each variable was calculated (i.e., hoof trimming frequency) and for continuous variables (i.e., water trough length/cow and passage width) the lower and upper quartiles were chosen to show the effect of the model.
2- Odds ratios for variables that showed a clear association with broken tails are bold.
3- Noise levels were based on the ability of two individuals standing 2 metres apart to communicate using their normal speaking voice: level 0 if speech was easily heard, level 1 if heard with difficulty, and level 2 if not heard at all.
4- Presence of cows who are holding their heads up in a crowded place such as the parlour holding area is a qualitative measure of high cow density.

5.4 Discussion

The in-pen versus parlour exit comparison identified that there was only limited agreement between the prevalence of broken tails identified in-pen and the prevalence identified at the parlour exit. Figure 5.2 shows that when the prevalence was low, scoring at parlour exit had on average a higher estimated prevalence than in-pen scoring, but this changed as prevalence increased. There is thus no simple conversion factor which will allow the prevalence at the parlour exit to be converted to the in-pen prevalence. Furthermore, even with a complex conversion factor (regression equation for the dotted line in Fig 5.2), the variability is still too great, as the limits of agreement are parallel to the regression line but are too wide (+ or - 24% compared to the prediction from the regression line). Observation inside the pen is likely to be more accurate than at the parlour exit as there is more time to observe the tail which is likely to reduce the number of false positive and false negative outcomes. However, neither may be ideal. In both situations we used simple observation to identify cows with broken tails (as this is the most commonly used method worldwide [155]). However, we believe that using palpation (as is recommended in New Zealand) alongside observation is likely to improve the accuracy of tail scoring (whilst acknowledging that this hypothesis needs testing). Palpation may be possible during in-pen scoring in farms that have locking head bales but might not be possible in pen systems without them. Further research is clearly needed to optimise tail scoring.

During the visits, the research team realised that even though most farmers were familiar with the concept of broken tails, there was a significant lack of understanding of the scale of the problem as many did not believe the recorded prevalence of broken tails on their farm unless the research team took them to a pen and counted the number of cows with a broken tail. Thus, 25 farmers were asked to estimate the number of or prevalence of cows with broken tails on their farms. Our data were not compatible with a strong positive relationship between a farmer's estimate of the number of broken tails on their farm and the number detected during in-pen scoring – the upper confidence limit for the effect of a 1% increase in the farmer estimate of prevalence on the odds of a cow having a broken tail diagnosed in-pen was 1.04. Our data were compatible with an increase in farmer prevalence estimates being associated with a decrease in in-pen prevalence (see Table 5-3). In contrast, a recent New Zealand study (Cuttance, unpublished data) reported a 3.32 (95% CI 1.25 to 8.82) times increase in the odds of a broken tail for every percent increase in farmers' estimates on damaged tails. These data clearly show that there needs to be significant education around tail damage on Iranian dairy farms. We believe that, based on the positive responses of our farmers being shown that their estimates were far too low, this is likely to be successful in reducing the prevalence of broken tails.

This risk factor study is only the second large-scale study on risk factors for broken tails in housed dairy cows after Crossley et al. [160]. However, it is important to note that the predictors tested in this study were collected as part of a welfare assessment rather than collected with the specific aim of identifying risk factors for broken tails. As such, compared to Crossley et al. [160], we have tested many fewer potential predictors. The predictors chosen for this analysis included variables related to human-animal relationship, cow density, cow flow management, and farming system. They were chosen for this analysis on the basis that they were collected on over 40 farms, and they were thought by the authors to be potentially related to tail damage. As such we used a full model with all 12 variables included with no selection procedure beyond ensuring a lack of collinearity.

This analysis identified three factors (trimming frequency, width of transfer passage and water trough space) where there was clear evidence of an association (i.e. our data were not compatible with an OR of 1). For the first two, we believe that the association is likely to be linked to poor animal handling. This is particularly the case for trimming frequency. The predicted marginal prevalence of broken cattle tails was higher on farms that trimmed the hooves more than 2 times a year than on those which trimmed < 2 times a year (87.7%, vs 59.5% respectively). We only saw standing trimming chutes during the visits (and not tilt tables) ranging from manual (older models) to newer electric and hydraulic chutes. During visits we regularly saw tail twisting being used to force the cows enter the trimming chutes. Twisting the tail is a commonly used technique to get cows to move has even been linked to "the ignition switch in a car" [161] but is considered to be one of the key causes of broken tails [150]. Furthermore, as cows possess long-term memory [162], a negative experience at the trimming chute at one time may discourage cows from entering it during subsequent visits. This can perpetuate a vicious cycle, leading to repeated tail twisting and thus an increased risk of tail breakages. No previous studies have identified hoof trimming (or using chutes) as a risk factor for broken tails; however, other studies have shown an association between human intervention and increased odds of broken tails. For example, Crossley et al. [160] found that farms that use a mixture of artificial insemination (AI) and natural mating had lower odds of broken tails than farms that used only AI (OR: 0.48; 95% CI: 0.27 to 0.85), while in a single farm Olsen et al. [62] reported a higher odds of broken tails on cows that had had two mastitis treatments versus those that had had one (OR: 1.84; 95% CI: 1.08 to 3.13) versus those that had not been treated for mastitis (OR: 1.36; 95% CI: 1.02 to 1.82). Furthermore, a recent New Zealand study reported a 1.18 (95%CI: 1.02 to 1.37) times higher odds of tail damage on farms that milked the cows twice versus once a day (unpublished data).

The negative association between the width of the transfer passage and the number of cows with broken tails in our study also suggest that animal handling plays a significant role in the development of tail breaks as wider passages mean that cattle can more easily move from the pen to the parlour without pushing. However, for other animal handling-related factors such as presence of cows with heads up in the holding area, and stockperson behaviour inside the parlour, our results were less clear. Although our data were compatible with heads up and using loud voice/hitting being associated with increased prevalence of broken tails, they were also compatible with these factors being associated with a decreased prevalence. Further research is required to better understand how handling and cow flow-related measures affect the prevalence of broken tails on Iranian farms.

The effect of water trough space on the odds of a broken tail were unexpected. We hypothesised that increased space (and thus lower cow density) would be associated with less broken tails, however less space was associated with fewer broken tails. The mode predicted that changing from the lower quartile to the upper quartile in trough length per cow would increase broken tail prevalence from 54% to 68%, respectively. This finding was consistent with our point estimate for feed trough space per cows which also suggested that less space was associated with fewer broken tails (although for feed trough length/cow our data were also compatible with no effect, see Table 5-3). Further research is required to establish whether feed and water trough length are a proxy for other factors related to broken tails or whether they have no effect and the findings in this study are just a chance finding.

For the rest of the variables included in our analysis, we came to no conclusions as to what their likely impact was on the prevalence of broken tails. This may be because, even though we anticipated that they might produce an effect, we lacked the power to accurately characterise their impact or, despite our belief that they would have an impact, they actually have no impact. We need more data, especially on Iranian farms as the prevalence of broken tails on our study farms is far higher than reported elsewhere in the world (see Fig 5.3). The only similar prevalence in the peer-reviewed literature was the 46% reported in a single farm in the US [62]. That farm was specifically chosen as it had a broken tails problem, and yet its prevalence was less than the 52% we observed on the study farms.

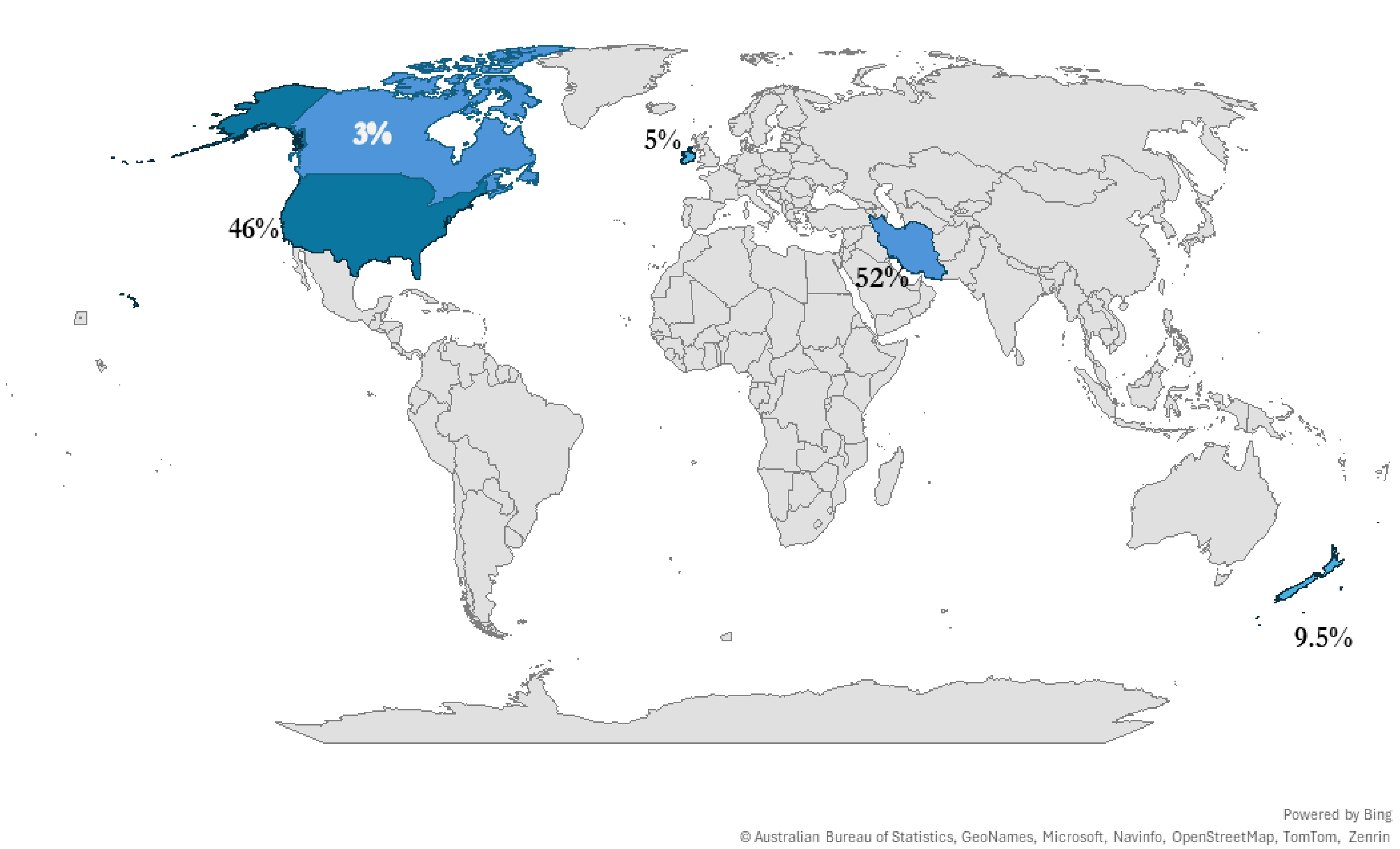

Figure 5.3. Countries with peer-reviewed papers reporting the prevalence of broken tails and the median prevalences. These include Iran, New Zealand, Ireland, Canada, and the United Sates (The study in the USA is done on a single dairy farm)

5.5 Conclusion

This study has highlighted the lack of data around broken tails, especially in relation to their aetiology. Our data strongly suggest that tail scoring needs time to be done accurately, so needs to be done in-pen (if scoring is observation only) or in-parlour/holding facility (if observation and palpation are to be used). Much further data are needed on the risk factors associated with broken tails, but our data add further to the suggestion that it is human-animal interaction that is driving tail breakage. Urgent action needs to be taken to reduce the prevalence of broken tails on Iranian dairy farms. This needs to start with educating farmers and farm staff on the problem.

General Discussion

This is the first systematic assessment of dairy cattle welfare in Iran. Previous studies have examined individual animal-based measures included in this study, such as body condition score (BCS) (e.g., Beiranvand et al. [53]) and lameness (e.g., Mohammadnia [23]). However, to date, no study has systematically recorded and compared multiple welfare indicators at the individual farm level. This limited emphasis on welfare assessment was evident in the lack of familiarity with the term 'animal welfare' among many of the farmers participating in this study and their lack of awareness of many of the welfare issues that we assessed. For example, even though most farmers were familiar with the concept of broken tails, there was a notable lack of awareness regarding the extent of the issue. Many did not accept the recorded prevalence on their farms until they went to a pen with the researchers and counted the number of cows with broken tails. However, once they were aware of the magnitude of the problem, they clearly expressed their intention to adopt necessary management practices to address and reduce the problem (such as group discussion with staff). This highlights the value of ongoing welfare assessment programmes in countries such as Iran, because as well as identifying the welfare problems at the individual farm level and at the industry level, it provides a means to teach and educate farmers about animal welfare and its importance. We thus strongly believe that assessments such as the one used in this thesis need to become a regular part of dairy farming in Iran, in order to optimise welfare on farm. Given Iran's current challenges (intensified in the last 15 years) which extend beyond economic recession and encompass significant political instability and social unrest, we recognise that this is unlikely to occur in the near future. However, it is also important to recognise that the economic and political uncertainty will also be negatively impacting overall farm performance and as a result the cow welfare.

Nevertheless, in some areas, we found that the welfare of Iranian dairy cows was generally good. This was particularly so for body condition – our principal measure of whether medium-term nutrition was having a negative impact on welfare. We found that median (IQR) BCS was 2.75 (2.75 to 2.88) with minimal variation within and between herds. Various BCS thresholds are used in different studies which makes direct comparison difficult. The mean prevalence of cows with low BCS (i.e., <2.25) in this study was 0.49%, while Adams et al. [163] reported an average prevalence of 6.0% for cows with low BCS (i.e., ≤ 2.25) in the USA, and Jewell et al. [114] reported a prevalence of 20% cows with BCS ≤ 2.5 in Maritime, Canada. Nonetheless, this almost certainly reflects the importance of BCS management and feed availability in ensuring that milk production is optimised. Indeed, during the visits we realised that many farms had multiple staff members with postgraduate qualifications, including PhDs, predominantly in the field of animal nutrition, and except for one farm, all farms employed a full-time cattle nutritionist, engaged a contracted nutritionist, or utilised a combination of both. Overall, feed availability was good as there were multiple provisions of feed per day; however, feed trough space and hygiene did not meet recommendations on many farms despite cows having generally good BCS. This highlights the difficulty of interpretation of outcomes when resource- and animal-based measures disagree – i.e., does the insufficient feed trough space indicate a welfare issue even though BCS is good? Similar issues were identified with water troughs where although every pen (and, on some farms, the parlour exit) had a water point, water trough space and hygiene did not meet recommendations on many farms. Unlike feed, we did not have an animal-based measure to identify whether water availability was sufficient and as the study farms were all in semi-arid areas the lack of space and poor hygiene is likely to be more of an issue on these farms than on farms in more temperate areas. This is particularly important in Iran as during days with high temperature-humidity index, non-dominant cows avoid drinking water at the hottest point of the day to avoid competition with dominant cows [164]. Further investigation is needed as to the impact of insufficient feed and water space of the welfare of Iranian dairy cows.

However, in many areas we found generally poor welfare especially around hygiene and animal health. The median prevalences of cows with dirty lower legs, lameness, hock swelling, and tail damage being 100%, 33%, 41%, and 60%, respectively. The prevalence of tail damage, principally broken tails, is the highest ever reported prevalence of tail damage, while the other prevalences were close to the high end reported in North American studies (e.g., [57,165]). This lack of good welfare may reflect at least in part by significant lack of resources on many farms e.g. cooling systems (with one third of the farms having no fans over the resting and holding areas despite being in hot semi-arid area). Financial constraints are the primary reason for inadequate resource provision. For example, one farmer, whose stall bedding management was notably poor, reported being unable to add sand to the bedding for over two months due to a sharp increase in sand prices. This farmer had recently transitioned from a bedded-pack to a free-stall system aiming to enhance cow comfort and, in return, improve productivity. This pattern was observed on multiple occasions where the farmer assumed that transitioning to free-stall system can improve productivity without considering other critical factors such as the need to install cooling systems and ongoing costs of bedding maintenance. This may reflect a limited understanding of animal welfare and its integral role in both farm-level sustainability and the broader resilience of the dairy industry.

Thus, despite the prevailing economic, political, and social challenges, improving dairy cattle welfare in Iran remains imperative. Given our results, this urgency is underscored by two key factors: Firstly, cattle farming constitutes one of the country's largest private sectors. Consequently, the prosperity of the dairy farming sector is closely tied to the well-being of the broader population. Secondly, animal-welfare certified products will positively enhance the marketability of animal-based products [37,166]. Establishing a recognised welfare assessment and certification program in Iran would not only improve domestic credibility and customer satisfaction [8] but could also facilitate access to international export markets. A recent study [22] shows that farmers' practices regarding dairy cattle welfare are significantly influenced by their attitudes towards pro-animal behaviour, their perceived behavioural interactions (i.e., the farmer's perception of ease or difficulty of improving dairy cattle welfare, shaped by internal factors such as his/her abilities and skills, and external factors such as resources), and subjective norms (i.e., the farmer's perception of social pressure and expectations to enhance dairy cattle welfare). As such, increasing public awareness of dairy cattle welfare and establishing regulatory bodies represent promising strategies to enhance animal welfare in the country. Additionally, dairy companies could implement animal welfare labelling on their products and consider pricing adjustments that reflect the welfare conditions under which the products were produced. This not only addresses the preferences and expectations of domestic consumers but also has the potential to enhance export opportunities and generate increased revenue.

Several prerequisites must be met before this goal can be achieved. First, a recognised and well-established welfare assessment protocol is essential. Second, more comprehensive data are required to better understand the associations between the various risk factors identified in our study and, ideally, to identify additional risk factors. Third, the development of an actionable plan is necessary to guide farmers in addressing these challenges and improving dairy cattle welfare on their farms. This plan should be supported and endorsed by multiple stakeholders, including dairy companies and public organisations. Ideally, the action plan should begin by addressing issues related to the human–animal relationship, as this area appears to require immediate attention (evidenced by high number of cows with broken tails), and can be improved with minimal financial investment compared to resource-based issues. We acknowledge that this study, as the first of its kind in Iran, was intended to be a starting point towards a better understanding of the dairy cattle welfare in the country and identifying risk factors for some of the welfare issues (i.e., broken tails, lameness, and leg joint injuries) on Iranian dairy farms, not an end point.

Future Work and Applications

Future Work and Applications

Farming is the second largest industry in Iran after oil and gas and is the largest industry that directly involves the income of the people. There are more than five million heads of cattle in Iran, and there a high potential to enhance exports and increase revenue should the challenges be dealt with. The biggest challenge that the industry faces is related to the socio-economic-politic situation in the country, but even if these challenges are solved, Iranian dairy farming industry still faces several important issues that can influence the export market. One of these is certainly a lack of data on animal welfare and the existence of welfare schemes in the country. Therefore, developing a code of welfare for Iranian farms is a must.

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MASSEY UNIVERSITY
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UNIVERSITY OF NEW ZEALAND

Farm Name:	Farm Owner:	Date of Visit:
Observer:	Time of Audit:	Temperature:

University of Tehran

Form Z

Environment/ Management

Water Trough Length	Max. waiting time for parlor
Water Trough Hygiene	Parlor ventilation
Feed Trough Length	Parlor floor
Feed Trough Hygiene	Noise level in parlor
Shelter above the trough	Track condition
Choice of water Temp.	Distance to water after parlor
Dam-calf relation	Safe/clean bedding
Comfortable calving pens	Barn ventilation
Hoof trimming frequency	Animal density
Foot bath frequency	Manure removal
Personnel behavior	Shelter above the resting area

Free-stall design

Stalls with manure contamination	%
Dirt alley	Y/N
Stocking density	%
Brisket locator	Y/N
Width	Cm
Neck rail height	Cm
Neck rail distance to the rear curb	Cm
Adjustable neck rail	Y/N
Position of animals in the cubicles	

Farm Records

Total number of mastitis cases	
Total number of lameness cases	
Total mortality and culling	
Average Days Open	
Average Milk Yield (3.5% CMF)	
Average Fat (annual)	
Average Milking Days (DIM)	
Milk SCC	
Average Culling in the lactating herd	
Average Calf Mortality (<3 months)	
Calf mortality at birth	

Form A

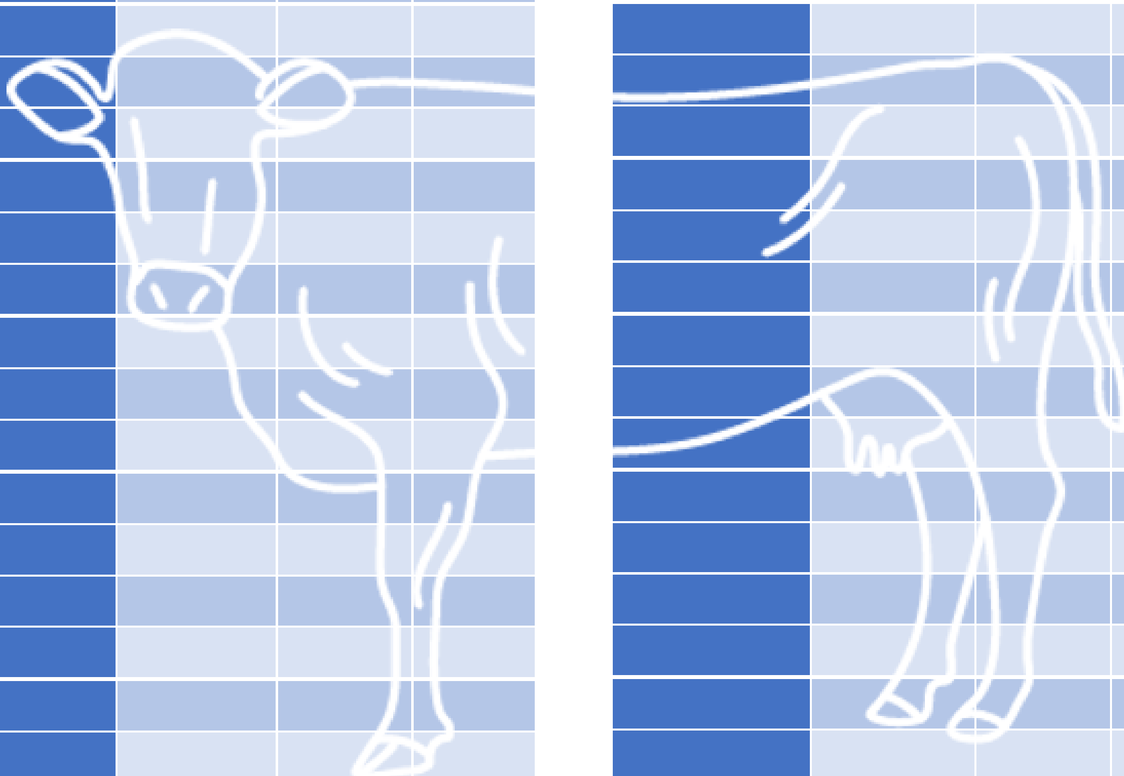
Cow No.	Hygiene				Injuries					BCS
	Lower Leg	Upper Leg	Tail	Udder	Hock	Knee	Neck	back	Other parts	

Cow No.	Hygiene				Injuries					BCS
	Lower Leg	Upper Leg	Tail	Udder	Hock	Knee	Neck	back	Other parts	

Form B

Cow No.	Avoidance	Discharge	
		Nasal	Ocular

Cow No.	Avoidance	Discharge	
		Nasal	Ocular



Form C

Cow No.	Lameness	NZ BCS	Tail

Cow No.	Lameness	NZ BCS	Tail

Cow No.	Temperature

Cow No.	Temperature

Papers used to develop a welfare assessment protocol that could be used on intensive dairy cattle farms in Iran

North America:

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