Welfare of the Dairy Cow

Dairy cows are susceptible to a range of serious welfare issues. These include health problems such as lameness and mastitis, infertility and high mortality or culling rates. Factors such as pasture access and comfort affect physical health, but also impact psychological well being and expression of natural behaviours. This information sheet outlines the main issues involved, and offers practical alternative solutions.

Pasture Access

A survey in the UK found 95% of the public surveyed thought it unacceptable to keep cows indoors permanently, whilst 73% thought it was acceptable to keep cows outdoors in summer and indoors in winter (Ellis *et al.* 2009). In a different survey (Canada), consumers rated animal welfare as the second most important priority (after food safety) (Maynard 2012). Scientific evidence shows that pasture access has proven benefits to cow welfare, for improved health, natural behaviour and access to a preferred environment, and to milk quality.

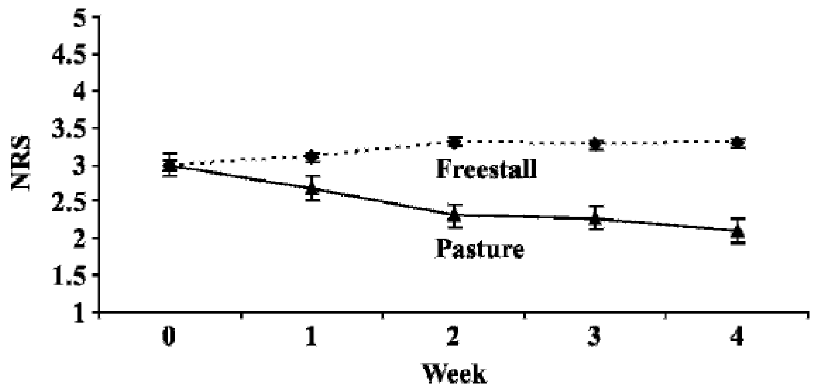
Preventing access to pasture was recently described as one of the top hazards to dairy cow welfare (EFSA 2009b, Rushen 2012). Public engagement is imperative to develop socially sustainable practices, which can persist in the long term (Weary *et al.* 2012), and pasture access is viewed as being important by the public (Ellis *et al.* 2009). In Europe the majority of farms provide seasonal grazing, with pasture access in summer and indoor housing for the other 5-7 months (EFSA 2009a). The extent of pasture access is determined by factors including herd size, pasture availability, distance from pasture to milking, weather conditions and supplementary feeding required for high-yielding cows (EFSA 2009a). The high metabolic demand of modern Holstein-Friesians has meant that some cows are now kept indoors all year round ('continuous housing'). In the EU, the highest reported approximate rates of continuous housing are in Germany (58%), Slovenia (60%) Denmark (75%), Czech Republic (80%), Spain (80%), Greece (85%) and Italy (90%) (EGF 2011, Webster 2012). In the UK approximately 10% of cows are now continuously housed (CIWF 2013 estimation, *pers. comms.*). The amount of access also varies within countries and between regions. For example in the Netherlands approximately 15% of cows are continuously housed and 52% have limited pasture access (EFSA 2009a, FAWC 2010); and in Germany 70-80% have some pasture access, but in Bavaria 84% are continuously housed (Webster 2012). In Sweden and Finland permanent-housing is illegal and cows must have access to pasture. Overall across the EU it is estimated that 38% of cows are kept continuously housed (Webster 2012, CIWF 2013 estimation, *pers. comms.*). Organic systems require unrestricted pasture access, except during winter, but account for only a small percentage of farms and derogations reduce the actual number with access.

Health

Pasture provides numerous health benefits including reductions in mortality, mastitis, metritis, teat trampling, dystocia, retained placenta and ketosis (EFSA 2009a). The effect of pasture on somatic cell count (SCC, a reliable indicator of udder infection) is unclear, but generally pasture reduces the risk of udder problems (EFSA 2009b). The most common problem from restricting grazing is lameness (EFSA 2009a). Studies world-wide have found hoof disorders and lameness are more prevalent in permanent-housing systems and during winter in seasonal-grazing systems (EFSA 2009a). Leg disorders such as Digital Dermatitis (DD), sole haemorrhage and swollen knees are also greater without pasture access. Good-condition pasture improves hoof health as it is a comfortable and healthy surface to stand on (Hernandez-Mendo *et al.* 2007). It allows normal walking and even weight distribution (Anderson 2008), whereas slippery floors cause them to walk abnormally to feel stable. Indoor housing increases the risk of leg disorders due to walking on concrete and spending time standing in manure (DCWS 2012). Pasture access after free-stall housing reduced sole lesions and improved claw puncture-resistance when measured 110 days later, which was associated with fewer foreign body penetrations, trauma and secondary claw infections (Winkler and Margerison 2012). This claw strength was likely due to the less concentrated diet and reduced metabolic stress later in lactation, as well as the pasture access.

Even a brief period of pasture access can help lame cows recover. Mobility scoring, which assesses the ability to walk, improved by an average of 0.22 (when measured on a scale of 1: normal to 5: severely lame) on pasture, compared to permanently-housed cows (Hernandez-Mendo *et al.* 2007), also supported by later findings (Figure 1). A long-term study found that cows on pasture had better locomotion, straighter rear legs, a steeper foot angle and healthier legs and hooves overall, compared to permanently-housed cows in cubicles, on a straw yard, or housed with access to a loafing area (Onyiro and Brotherstone 2008). Pasture access can increase the net growth-rate of hooves (growth rate / wear rate) (Chapinal *et al.* 2010), and therefore can improve hoof health. Lameness and hock swelling incidence during winter was lower on pasture than permanent-housing systems (Haskell *et al*. 2006). The length of winter housing also has an effect, as the prevalence of lameness increased after housing for 61 days or more (Barker *et al.* 2010). Exercise is important for health, as it reduces leg disorders and improves lying and rising transitions. Cows housed in tie-stalls, in which they are tied by the neck, were less likely to be lame when given regular exercise all year; and hock joint alterations and overall medical treatment were lower in loose housing with regular exercise than tie-stall housing with regular summer but little winter exercise (Regula *et al.* 2004). Other forms of exercise, such as access to a dry lot, are less beneficial to health than pasture-based exercise, in reducing mastitis and DD (EFSA 2009a).

Figure 1. Effect on locomotion score (numerical rating score 'NRS', score increases with level of lameness) after providing pasture access or free-stall housing (Hernandez-Mendo *et al.* 2006).



There are risks associated with pasture access, including bad weather, parasites, toxic plants, competition for food under high stocking densities, poor energy intake, and hoof problems due to water-logging or stony tracks. During transition (late pregnancy to early lactation) feed intake may be insufficient, especially with low fibre content. There can also be negative effects of exercise if cows have to walk too far (eg. to be milked) or too fast (>5km/hour). Subordinate cows use shade on pasture less often and are more willing to choose lower-quality shade to avoid dominant cows (Pinheiro Machado Filho *et al.* 2012). Cows are highly motivated to access shade in hot conditions (Schütz *et al.* 2008). Therefore to reduce competitive aggression, cows on pasture need sufficient high-quality shade or shelter, of at least $5m^2$ per cow (Schütz *et al.* 2012). Automatic Milking Systems (AMS) may be less suitable for pasture, as cows may be reluctant to be milked or to go to pasture if they are far apart. Cows visited their AMS less often with unrestricted, than restricted (0 or 12 hours/day) pasture access (Ketelaar-de Lauwere *et al.* 1999). Cows kept on pasture far-away also visited less often, however only for the start of the grazing season (Wiktorsson and Sporndly 2002). In addition, cattle synchronise their visit to an AMS when kept on pasture (Ketelaar-de Lauwere *et al.* 1999) and are adaptable to walking long distances. A well designed cow traffic system is required when using AMS in combination with pasture. Using one-way gates at the barn entrance and exit to pasture (Wiktorsson and Sporndly 2002), only allowing pasture access after using the AMS (Spörndly and Wredle 2004), or using operant conditioning to train cows to return from pasture to a noise signal (Wredle *et al.* 2006) will optimize cow traffic and limit the number requiring to be manually fetched (Jacobs and Siegford 2012). To achieve good health, particularly for hooves, cows need access to well-managed pasture or other outdoor areas, at least during summer and dry weather (EFSA 2009b), with supplementary feed during transition.

Behaviour

Pasture allows a greater range of natural behaviour expression. As many as 40 different categories of normal behaviour are defined in cattle (Kilgour 2012), many of which are not seen in modern dairy cows. The daily time budget of free-living cattle involves approximately 5-9 hours grazing, 5-10 hours ruminating, 4-10 hours resting and walking across distances of 1.7-12.6 km (Kilgour 2012). Modern dairy cows have a strong motivation for lying (EFSA 2009b) and lie for 9-14 hours a day, much longer than wild-living cattle (Anderson 2008, EFSA 2009a). It is affected by factors including space, stall comfort (O'Connell *et al.*1993), pasture condition, climate, age and parity. Cows lie less in muddy conditions, on wet bedding covered with faeces, in hot conditions, and on pasture fertilised with potassium instead of sodium; and more with age, more lactations, and in longer, fewer bouts on pasture than indoors (O'Connell *et al*. 1989; Singh *et al*. 1993, Phillips *et al.* 1999, Tucker *et al.* 2010, Steensels *et al.* 2012).

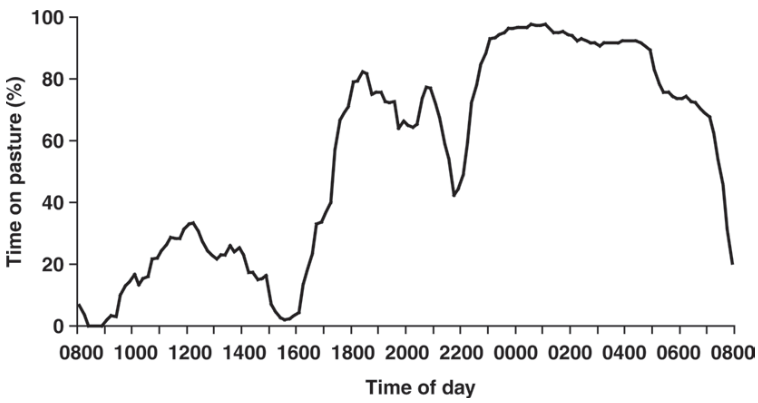
Lying is important to welfare for several reasons. Cows with pasture access can spend 80-99% of their lying time on pasture (Ketelaar-de Lauwere *et al.* 1999). Cows ruminate while lying (Steensels *et al.* 2012), which is needed for normal digestion and increases with increasing yield (Norring and Valros 2010). Lame cows can also spend longer lying, as found in permanently-housed cows (Blackie *et al.* 2011) and may be reluctant to rise after lying down. Tie-stall housed cows, many of which had hock inflammations, took longer to lie down than loose-housed cows with pasture access (Krohn *et al.* 1993). Cows spent longer lying on a woodchip surface than when kept on concrete, gravel or paddock surfaces. Cows on these other surfaces spent longer lying during 3 hours of restricted pasture access (Fisher *et al.* 2003). This suggests limiting pasture access, such as during periods of bad weather, compromises grazing and consequently health, as cows prioritise lying on the comfortable surface instead. Restricting pasture access from 8 to 4 hours per day also reduces dry matter intake and milk yield (Mattiauda 2013).

Social and grooming behaviour is also affected by pasture access. Cows performed less excessive sniffing and licking of other cows, equipment or the ground on pasture than in tie-stalls; and one hour of outdoor exercise in tie stall systems reduced the behaviour, indicating tie stalls are under-stimulating (Anderson 2008). Confinement also increases aggression and reduces benign interactions (O'Connell *et al.* 1989), presumably because cows are prevented from normal interactions to determine social hierarchy. Agonistic interactions can be much higher in indoor free-stall systems than on pasture (Miller and Wood-Gush 1991). This is likely due to space, because the restricted space allowance prevents them avoiding aggressive individuals. Behaviour indoors in free-stall housing with inadequate space for lying and rising appears worse than on pasture (Schrer and Pelzer 2006). However, with a spacious, comfortable lying area and rubber flooring, behaviour indoors can be similar to pasture (cited in Anderson 2008). Pasture has a relaxing, stress-reducing effect on cows when indoors later that day, particularly for low-ranking cows which experience the most social stress (Irrgang and Knierim 2012). Longer pasture access (8 compared to 4 hours) improved the relaxing effects, indicated through lower heart rates and less aggressive interactions; while cows with no pasture access had the highest stress levels indoors (Irrang and Knierim 2012).

Preference for Pasture

Cows show a general preference for being on pasture (for ~50% of the day, as shown in Figure 2), but this is affected by different factors including nutrition. Long-term genetic selection for milk yield has changed the form, size, spatial requirements and metabolic demands of modern dairy cows, which now produce an average milk yield of 28L per day, and individual cows can produce twice this (EFSA 2009b, Huxley and Green 2010). Cows offered a choice after milking between going indoors with total mixed ration (TMR) or to pasture chose indoors almost twice as often and spent more time indoors (Charlton *et al.* 2011). Fresh TMR provided after morning milking probably encouraged the cows to go indoors. High-yielding cows spent longer indoors, whereas cows with a high body-condition score spent longer outdoors (Charlton *et al.* 2011). The cows on pasture spent almost half of their time grazing, which suggests that when their nutritional needs are met, they prefer pasture. Cows showed a partial preference for pasture (71% of time), between indoors or pasture-only, which was unaffected by TMR provision in both locations (Charlton *et al.* 2010). As food supplementation increases and pasture access is restricted cows spend more time indoors (Wiktorsson and Sporndly 2002). Those in late lactation spent 13 hours per day, mostly at night, on pasture when given the choice, with less than 1/3 of time on pasture between morning and evening milking (Legrand *et al.* 2009). The cows also lay more on pasture than in free-stalls, but lay for longer overall when offered the choice of indoors and pasture. TMR intake also reduced by 14% compared to permanently-housed cows, which may be unsuitable for cows in early lactation. The time cows spent on pasture during the day decreased with increasing temperature-humidity index and decreased at night with rainfall (Legrand *et al.* 2009). This preference for pasture at night and indoor free-stall housing (with TMR) during the day has been recently supported (Falk *et al.* 2012).

Figure 2. Time spent on pasture through the day with access to free-stall housing and pasture (Legrand *et al.* 2009).



Climate also affects pasture preference. During rain, which can reduce skin temperature by 26% (Schutz *et al.* 2010), cows chose to go indoors more than to pasture (Wiktorsson and Sporndly 2002, Charlton *et al.* 2011, Falk *et al.* 2012). When given the choice between shelter without food, or food outdoors with rain and wind, cows chose the shelter and ate 62% less (Schutz *et al.* 2010). Excessive heat also reduces the willingness to use pasture. Modern dairy cattle are susceptible to heat stress due to metabolic heat production (EFSA 2009b) and generally cannot cool themselves above 25^{o}C. At temperatures >25^{o}C, cows chose to stand in shade rather than lie in sunlight, even after being deprived of lying for 12 hours (Schutz *et al*. 2008). This shows that shade is more important than lying at high temperatures. With every degree increase in temperature (temperature humidity index range 32.5-77.4), cows spent 2.13 less minutes outside (Hanna *et al.* 2010). Cows also feel uncomfortable in high humidity, and cows with free pasture access spent less time outdoors between 10.00-17.00h (Ketelaar-de Lauwere *et al.* 1999). Lying time indoors also increases in higher temperature and humidity (Falk *et al.* 2012). When cows were given access to a self-activated shower, they used the shower for

0.3 hours more for every 1°C increase in temperature (Legrand *et al*. 2011). In contrast, it is often perceived as being unsuitable to put dairy cows outdoors during winter. They have been found to spend less time on pasture as the season changes from summer to winter (Charlton *et al.* 2010). During summer, cows spent ~17 hours/day outdoors when given the choice, including most of the night (Krohn *et al.* 1992). In winter this reduced to ~5 hours, to 0 hours on frosty days, but they did spend 1-3 hours outdoors on some winter nights. When offered a choice for 3 hours, all cows went outside for one hour and most for 3 hours, during weather which ranged from sun to high wind and snow (temperatures -11 to +7 °C) (Vasseur and Bergeron 2012). Cows spent most of the first hour outside at the feeder. Availability of free-stalls did not affect the time on pasture, which suggests that cows preferred using indoor housing to eat and escape poor weather, rather than for lying in stalls (Falk *et al.* 2012).

A reduced dry feed intake and milk yield is one reason that dairy cows may not be given pasture access, particularly after milking (Soriano *et al.* 2001). However cows are highly motivated to eat during the day (DeVries 2003), and indoor-housed cows consume 80% of their daily dry matter intake in the evening (Huzzey *et al.* 2007). Allowing cows overnight pasture access can provide a practical solution to pasture access which avoids compromising feed intake. Holstein cattle fed indoors during the day and given overnight pasture access (temperature 4-37°C) had no negative effects on dry matter intake, body condition, lying time or milk production; compared to permanently-housed cows (Chapinal *et al.* 2010). Dairy heifers' do not show a preference for pasture if they have not had previous experience, as they learn naturally to use pasture through social facilitation and grazing is a learned behaviour (Motupalli *et al.* 2013). Additionally, cows have been shown to be equally motivated to access pasture as TMR after milking (Cestari *et al.* 2013). When good quality pasture is unavailable, loafing areas can provide cows outdoor access. Loafing is any behaviour that is not related to feeding, milking or calving, and the area is used by cows for oestrus behaviour, socialising, grooming and exploring (Langford *et al.* 2013). Concrete loafing areas are laborious to clean and unsuitable for lying, whereas a grassy paddock loafing area is preferred by cows and will be used more for lying by cows that are housed in free stalls (Langford *et al.* 2013).

Overall, in wet or very cold conditions, cows prefer to be indoors. In warm conditions (~9-24°C) low-yielding and high body-condition cows, with experience of it, prefer pasture, whilst high-yielding cows prefer to be indoors during the day and on pasture at night. In hot conditions (>25°C), cows prefer pasture at night, or during the day with shade. Free-stall housing strengthens the preference, as cows prefer pasture to lie on. If feed, water and shade are provided in housing and on pasture, cows can make a choice, which is the gold standard for welfare. When pasture is unavailable, loafing areas can provide outdoor access.

Milk Quality

There are significant nutritional benefits to milk produced from cows fed pasture-based diets compared to cereal based and TMR diets. These include higher levels of important fatty acids (White *et al.* 2001; Bergamo *et al.* 2003; Walker et al, 2004; Butler et al, 2008), vitamins and minerals (Bergamo *et al.* 2003; Butler *et al.* 2008), and lower total milk fat percentage (White *et al.* 2001). Omega-3 fatty acids, linked to improved neurological function and protection against coronary heart disease and some cancers (Ellis *et al.* 2006), are greater in milk from cows in low-input, pasture-based systems than high-input concentrate-based systems. Additionally, the ratio of omega-3 to omega-6 is found to be closer to the recommended levels to achieve good health (Butler *et al.* 2008) in milk from pasture-fed cows. Organic milk has higher concentrations of beneficial fatty acids than conventional milk, including total polyunsaturated fatty acids (PUFA), conjugated linoleic acid (CLA) and α-linolenic acid (Bergamo *et al.* 2003. CLA and PUFA are also higher in milk from cows given pasture access (White *et al.* 2001; Walker *et al.* 2004; Butler *et al.* 2008). CLAs have been shown to have potential anti-carcinogenic and anti-atherosclerotic effects (heart health benefits) (Ellis *et al.* 2006) and can even help to reduce body fat levels (DeLany and West 2000). Increasing the level of pasture intake increases the levels of

CLA (Butler *et al.* 2008), and importantly CLA levels are 50% higher when pasture is grazed as opposed to fed as cut-grass (Offer, 2002), indicating the importance of grazing pasture. β-carotene, lutein (both important for eye health) and α- tocopherol (a form of vitamin E) is also significantly higher in milk from low input systems.

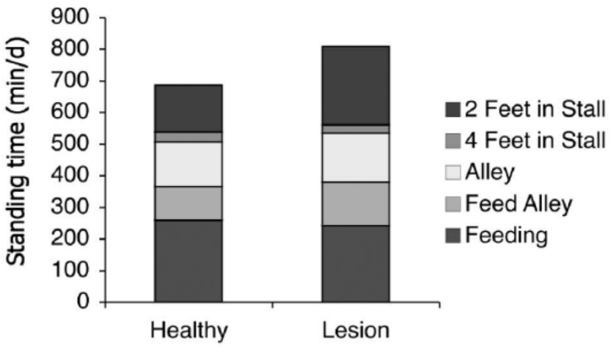
Lameness

Lameness is a multi-factorial disease, and is typically a symptom of infectious disease, such as foot rot and DD, and non-infectious disease, such as sole ulcers, sole haemorrhages or white line lesions (Keyserlingk *et al*. 2009). It is a serious welfare issue which results in multiple problems including pain, reduced body condition, reduced milk yield, reduced dry matter intake, reduced fertility and an increased likelihood of culling . In Europe, the level of lameness has not reduced for the last 20 years (EFSA 2009b). In a UK survey (of 205 farms, across a range of systems during winter), the mean prevalence of lameness was 36.8% (range 0-79%) and 5.3% (range 0-31%) of cows were severely lame (Barker *et al.* 2010). FAWC (2009) recommend that the incidence of lameness should be urgently reduced. Awareness of the costs associated can provide encouragement for proactive management, as lameness costs an average of €53 per cow every year, and DD causes the highest financial burden (Bruijnis *et al.* 2012).

Locomotion and bone quality were found to be poorer in free-stall housing than in other systems (straw yard, pasture or loafing systems); whilst locomotion, foot angle and mammary composite score were worse on straw yards than pasture (Onyiro and Brotherstone 2008). Lameness was lower in pasture than permanently-housed herds, as were knee swellings; and lameness was highest in permanently-housed free-stall, compared to straw yard systems (Haskell *et al.* 2006). Lameness levels were lower on organic than conventional farms (Barker *et al.* 2010). Mobility improved significantly in lame cows when put on pasture for 4 weeks, whereas those in indoor housing remained stable or got worse (Hernandez-Mendo *et al.* 2007). As discussed, pasture can be hugely beneficial for lameness. However, poor hoof health can occur if pasture is poorly maintained. Levels of DD and interdigital dermatitis and sole and heel lesions can be higher on pasture than indoors (Baird *et al.* 2008, EFSA 2009a), although cows with DD had lower maximum heel erosion scores on pasture than indoor cows (Baird *et al.* 2008).

Other risk factors for lameness include standing in manure and on wet floors, overcrowding, dirty or inconsistent use of footbaths, poor management of silage, food sorting (which reduces nutrient intake), stress, poor claw maintenance, automatic alleyway scrapers (which coat hooves in manure) and slippery floor surfaces (DCWS 2012). Breed also has an effect, as Holstein-Friesians had poorer claw health than Norwegian cows (Baird *et al.* 2008). Too few or undersized free-stalls can cause 'perching', when cows stand with their front feet perched on the stall, which leads to lameness. Standing indoors for long periods before calving, particularly perching, increased the risk of sole ulcers or severe haemorrhage later in lactation (Figure 3, Dippel *et al.* 2011). This highlights the importance of good housing design, with comfortable lying areas to minimize perching.

Figure 3. Standing behaviour of cows for 2 weeks before calving, diagnosed as healthy or with a lesion 15 weeks after calving (Dippel *et al.* 2011).

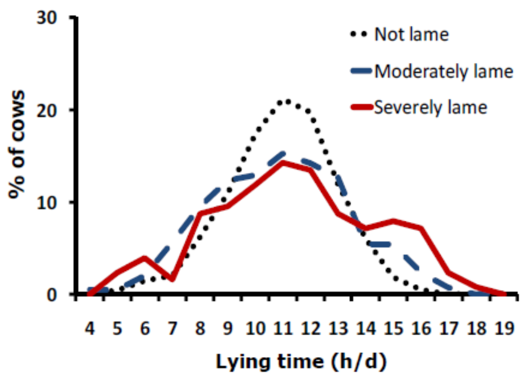


Cows on pasture required to walk long distances (eg. 700m) on stony outdoor tracks can have poor condition hooves, though track quality is more important than the distance walked (Laven 2012). Hoof lesions also increased on solid concrete floors compared to straw yards (Webster 2002, Somers *et al.* 2003), slatted floors (Frankena *et al.* 1992) and rubber floors (Hultgren and Bergsten 2001). Lameness is also increased by damaged or slurry-covered concrete, cows pushing each other in yards and slipping, housing for more than 61 days and not treating within 48 hours of incidence (Van de Tol *et al.* 2005, Barker *et al.* 2010). Breeds other than Holstein-Friesians have a lower risk of lameness, independent of milk yield.

"If you don't measure it, you can't manage it. The key to preventing lameness is to keep feet *clean* and *dry*". (DCWS 2012)

Management is essential to prevent and treat lameness, but may not be applied due to a lack of time or labour, inadequate hoof-trimming facilities or cost (Whay 2012). Locomotion scoring should be frequently carried out on every cow; the Dairy Co 4-point Mobility Scoring System is an example of a standard, easy to use system. To be scored accurately, cows should walk on a flat, even surface, in a straight line or around a corner, and ideally by an impartial person. Cows identified as lame should then be promptly diagnosed and treated, as early detection and treatment improves the likelihood of recovery (Dairy Co 2013a). EFSA (2009b) recommend that locomotion scoring and foot lesion assessment should be carried out every 3 months, and if 10% or more of the herd have difficulties, changes should be made to housing, management and genetic strain. They consider a 2% level of lameness achievable on commercial farms. Observing cattle in pasture systems can be difficult and time consuming (Siegford *et al.* 2012), but accelerometers (leg monitors) are a useful tool which can be used to record behaviour including reduced or excessive lying (<9 or >14 hours, as shown in Figure 4), which indicates lameness, as well as feed intake and reproductive status (Siegford *et al.* 2012, Solano *et al.* 2012). Hoof trimming, such as Dutch 5-step trimming (Nadis 2009), should be practiced when necessary to treat and prevent lameness. It is now recommended that claws should not be trimmed to a fixed length due to the variation between individuals (Blowey and Inman 2012). Particular care should also be taken when trimming feet with lesions, to not remove excess horn (Blowey and Inman 2012). Non-Steroidal Anti Inflammatory Drugs (NSAIDs) should be considered during treatment for lameness, as procedures such as hoof trimming can be painful, and used routinely for claw horn disease (Laven 2012).

Figure 4. Lying behaviour of cows that were not lame, moderately lame or severely lame (Ito *et al.* 2009).



Further measures to prevent and treat lameness include regularly using a footbath, ideally daily after milking (depending on the chemical used); keeping housing areas clean and dry; good nutrition and providing a comfortable recovery area for lame cows (DCWS 2012). EFSA (2009a) stress that for the welfare of the cow, the full range of outdoor and indoor conditions count, so that welfare is "cumulative and interactive". For example, improved claw health on pasture prevents lameness and reduces sensitivity to hard floors surface during indoor housing.

Mastitis

Mastitis is a common, painful disease caused by multiple factors. Cows with mastitis show a withdrawal from normal behaviour and changes include reduced lying, an increased preference for lying on one side, more walking and weight-shifting, and higher reactivity and restlessness during milking (Medrano-Galarza *et al.* 2012). These indicators can be used to detect moderate to severe mastitis, but mild mastitis causes only minor changes in lying and behaviour during milking which indicates discomfort. Detecting and alleviating pain caused by mastitis is also commonly overlooked (Medrano-Galarza *et al.* 2012). Mastitis can cause serious financial losses to dairy farmers. Modelling (based on real data) predicted that as mastitis levels increase profits reduce, and farms with the highest levels of mastitis (Bulk SCC >400,000 cells/mL) had 62% less profits than those with the lowest rates of mastitis (Bulk SCC <100,000 cells/mL) (Geary *et al.* 2012). Clinical and sub-clinical mastitis also causes reproductive performance to suffer (Geary *et al.* 2012).

In conventional systems, udder health is largely maintained by the use of antimicrobials, leading to concerns that mastitis will be worse in organic systems because of restricted antibiotic use. There are conflicting results as to whether SCC levels from organic farms are higher (Hovi and Roderick 2000, Roesch *et al*. 2007), lower (Sato *et al*. 2005; Fall *et al*. 2008) or equivalent (Busato *et al.* 2000) to levels from conventional (non-organic) farms. However, a recent large scale study of individual cows on 40 organic and 40 non-organic farms in the UK found that organic systems and straw yard housing did not influence SCC (Haskell *et al.* 2009). Additionally, rotational grazing reduced the risk of mastitis compared to permanently housed or constant pasture systems, and non-*agalactiae streptococci* was lowest in rotational systems (Goldberg *et al*. 1992). Green *et al.* (2007) also found no evidence that straw yard housing increased the risk of mastitis and confirmed the benefit of rotational grazing over constant grazing for lowering mastitis risk. SCC appears to be generally lower in summer, regardless of the type of system and varies hugely between individual farms (Frelich and Slata 2011).

One of the main risk factors for mastitis and elevated SCC is poor hygiene, which is more likely to occur in multi-parous and high-yielding cows (DeVries *et al.* 2012). Older cows have larger, deeper udders which are more likely to get covered in manure nearer the floor, and higher-yielding cows are required to eat more, which increases their risk of dirty hind limbs as they spend longer standing in the feed bunk alley (DeVries *et al.* 2012). Mastitis can be managed by providing a clean environment for standing (eg. feeding area and alleyways) and lying, particularly in free-stalls (Devries *et al.* 2012). Encouraging cows to stand after milking by providing feed allows their teats to close before lying down, as standing for <90 minutes after milking could increase SCC (Devries *et al.* 2012, Watters *et al.* 2012). Further measures which can reduce mastitis are pasture access (due to the lower infection pressure); keeping late-gestation heifers with the herd (which is less stressful than mixing post-partum); removing super-numerary teats (to improved udder hygiene, ensuring analgesia is given); and not using an AMS (perhaps due to their reduced efficiency at teat cleaning and detecting sub-clinical mastitis or limited access for some individuals) (Santman-Berends *et al.* 2012, Wagner *et al.* 2012). To help manage mastitis, SCC should be measured at the individual, not herd level. An extra staff member in the milking pit can help identify mastitis and milking teat cup liners should be changed every 2500 milkings, which is equivalent to monthly for some herds (DairyCo 2013b). The six-point plan for controlling mastitis comprises 1) hygienic teat management, 2) prompt identification and treatment of clinical mastitis, 3) dry cow management and therapy (for infected cows) 4) culling chronically affected cows, 5) regular maintenance of the milking machine and 6) good record keeping (DairyCo 2013c).

Comfort

Keeping dairy cows in tie stalls, which are common in more traditional systems, present multiple welfare issues. Movement and exercise are severely restricted, grooming and social interaction is impaired (Anderson 2008), there is an increased risk of lameness and hock inflammation (Krohn and Munksgaard 1993, Regula *et al.* 2005,) cows are unable to escape dominant individuals (EFSA 2009b) and stalls can be poorly fitting. The use of electric shocks to train cows to excrete outside of the stall causes physical problems (Oltenacu *et al.* 1998 cited in EFSA 2009b) and will cause stress, and tethering tails prevents cows being able to deter flies. A recent survey of 226 farms across Europe found that 35% of cows were kept in tie stalls, particularly in Eastern countries and central and southern mountainous regions (Alcasade 2009). Tie stalls are becoming less common and are not normally permitted in European Organic systems.

The majority of European dairy cows are now housed in free-stall barns (EFSA 2009a). These contain cubicles, which may consist of a mattress with some or no bedding, soil covered with straw, or deep-bedding, such as sawdust or sand. There are commonly the same number of cows as stalls, and in many systems, stall dimensions may be too small for the modern Holstein-Friesian cow. Modern dairy cows lie for 12 hours a day and become stressed if deprived of lying; shown by behavioural and physiological indicators (Fisher *et al.* 2002, Jensen *et al*. 2004, Munksgaard and Thomsen 2012). Cows may prioritise lying, although a conflict may arise in high-yielding cows between lying and eating. Reduced lying can also reduce food intake and yield (Munksgaard and Thomsen 2012). It is important that the lying area is comfortable and meets their needs, particularly because hock lesions can become more prevalent during lactation (Tucker *et al.* 2012). Figure 5 shows a outcome based checklist that can be carried out to assess comfort levels on farm.

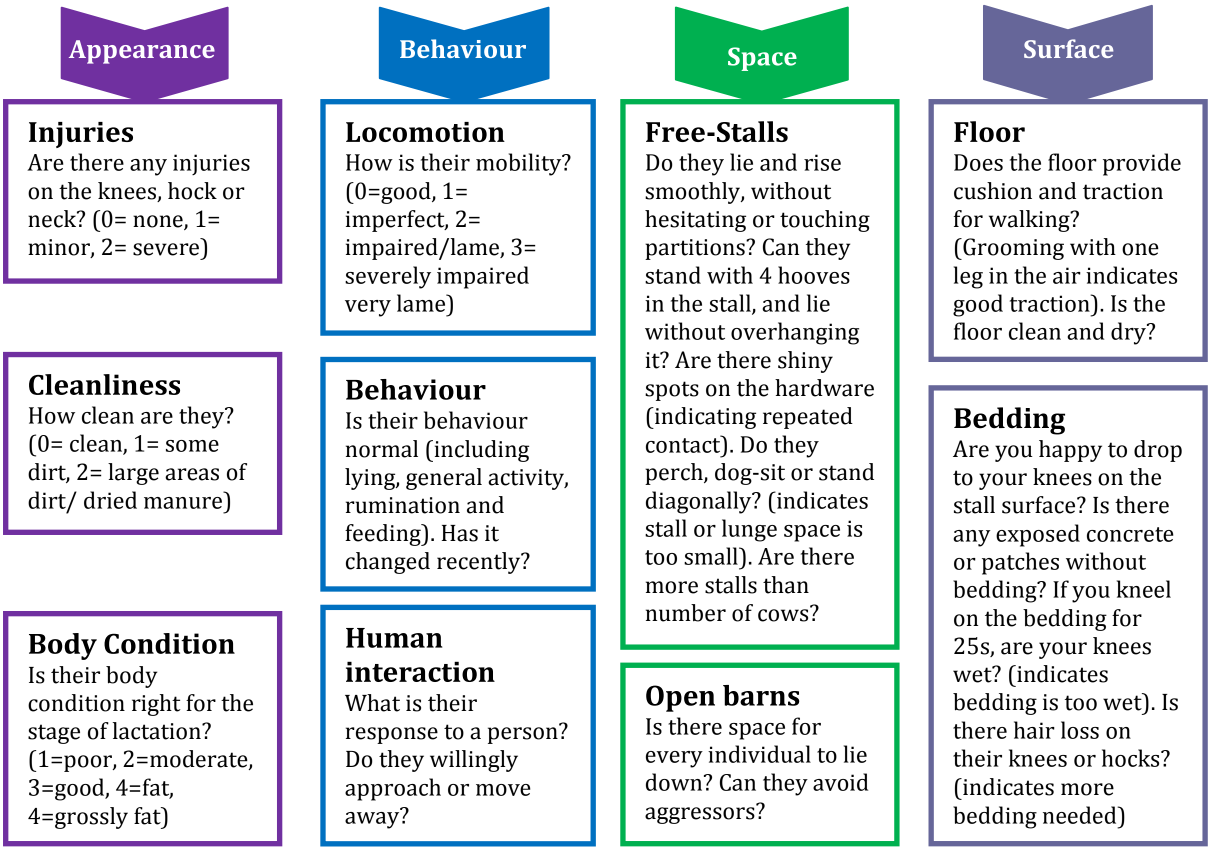
Bedding has different effects on comfort and health. Deep-bedded sand improves milk yield and is better for welfare (for cleanliness, hock condition and lameness) than free-stalls with rubber mats or mattresses (Andreasan and Forkman 2012), but is not always practical to use. Deep-bedded open barns are uncommon in Europe, but more popular in North America, where different bedding materials are utilised, such as peat moss and recycled manure solids (RMS). RMS is produced by a liquid-solid separator, anaerobic digester or composter (DCWS 2012) and originated in the USA, but has spread to Israel and the Netherlands. Well-managed, deep-bedded RMS barns with good ventilation improve welfare by reducing lameness and voluntary culling due to poor milk yield and improving SCC, cleanliness, comfort, lying time, freedom of lying positions, sleep, and oestrus and play behaviour, compared to mattress stalls with some RMS (Black *et al.* 2012, Husfeldt and Endres 2012).

Open barns also allow cows to lie laterally, which is restricted in free-stall housing (Langford *et al.* 2013) and is when most REM sleep occurs (essential for the brain and important for learning and memory) (Capellini *et al.* 2008). Open barn housing or pasture also allows cows to lie in their preferred orientation and near companions. In Europe, Holstein and Jersey cows lie and feed for longer in open deep straw-bedded than free-stall housing (Campler *et al.* 2012). Cows given a grassy paddock loafing area used it for lying if they were housed in free stalls, or loafing if they were kept in deep straw barns (Langford *et al.* 2013), which shows the difference in lying comfort between the systems. Improved cow comfort has also been associated with improved milk yield (van Eerdenburg *et al.* 2012).

Mortality

Mortality levels in dairy cows are increasing (Thomsen *et al.* 2004, McConnel *et al* 2008). Risks associated with higher mortality include increasing herd size, average milk yield and morbidity, respiratory disease, and TMR feeding (McConnel *et al.* 2008, Thomsen and Sorensen 2009). Mortality is associated with negative psychological states, as chronic stress reduces immunity which can lead to disease and mortality (Walker *et al.* 2012). The risk of mortality was lower in organic Danish than conventional, summer-grazed herds (Thomsen *et al.* 2006). Cull rates in the UK were 23.8% in the early 90's (Esslemont and Kossaibati 1997); 22% were sold and 1.8% died on-farm. Disposals were attributed to poor fertility (36.5% of total), management policy (11.5%),

Figure 5. Welfare outcomes-based assessment of dairy cow comfort (DCWS 2012)



mastitis (10.1%), and lameness (5.6%). By the late 1990's UK cull rates were still similar at 22.1% (Whitaker *et al.* 2000), with infertility, mastitis and lameness rates responsible for >50% culls and accounting for annual rates of 5.6, 3.6 and 1.7%, respectively. Involuntary culling refers to disposal due to injury, poor health (commonly mastitis and lameness) or infertility. It may involve a trade-off between the optimum finance for the farmer and the humane endpoint for the cow (Langford and Stott 2012). Investment to reduce the causes of mortality is beneficial in the long-term and reduces the need for culling and the poor welfare experienced by untreated cull cows (Langford and Stott 2012).

References

Alcasade (2009) Alternatives to Castration and Dehorning. Study on the improved methods for animal-friendly production, in particular on alternatives to the castration of pigs and on alternatives to the dehorning of cattle (SANCO/2008/D5/018). Appendix 20, D.2.1.1. Report on dehorning practices across EU member states. pp211-219.

Anderson, N. (2008) Cow behaviour to judge free-stall and tie-stall barns. Information sheet, Available at www.ontario.ca/omafra. Last accessed 15/02/13.

Andreasen, S.N. and Forkman, B. (2012) The welfare of dairy cows is improved in relation to cleanliness and integument alterations on the hocks and lameness when sand is used as stall surface. *Journal of Dairy Science* 95, 4961-4967.

Agricultural Research (2011) Putting Dairy Cows Out to Pasture: An Environmental Plus" May/June 2011 issue of *Agricultural Research* magazine. Available at http://www.ars.usda.gov/is/AR/2011/may11/cows0511.htm. Accessed 15/02/13.

Baird, L.G., O'Connell, N.E., McCoy, M.A., Keady, T.W.J. and Kilpatrick, D.J. (2008) Effects of breed and production system on lameness parameters in dairy cattle. *Journal of Dairy Science*, 92, 2174-2182.

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

Bergamo, P., Fedele, E., Iannibelli, L. and Marzillo, G. (2003) Fat-soluble vitamin contents and and fatty acid composition in organic and conventional Italian dairy products, *Food Chemistry*, 83, 625-631.

Black, R., Taraba, J., Day, G., Damasceno, F., Bewley, J. (2012) Potential cow-focused benefits of compost bedded pack dairy barns. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Blackie, N., Amory, J., Bleach, E. And Scaife, J. (2011) The effect of lameness on lying behaviour of zero-grazed Holsterin dairy cattle. *Applied Animal Behaviour Science* 134, 85-91.

Blowey, R. and Inman, I. (2012) Is there a case for reassessing hoof-trimming protocols? *Veterinary Record*, 171, 592-593.

Bruijnis, M.R.N., Beerda, B., Hogeveen, H. and Stassen, E.N. (2012). Foot disorders in dairy cattle: impact on cow and dairy farmer. *Animal Welfare,* 21, 33-40.

Busato, A., P. Trachsel, M. Schallibaum, and J. W. Blum. (2000). Udderhealth and risk factors of subclinical mastitis in organic dairy farms in Switzerland. *Preventative Veterinary Medicine*, 44, 205–220.

Butler, G., Nielsen, J. H., Slots, T., Seal, C., Eyre, M., Sanderson, R., Leifert, C. (2008). Fatty acid and fat-soluble antioxidant concentrations in milk from high- and low-input conventional and organic systems: seasonal variation. *Journal of the Science of Food and Agriculture*, 88, 1431-1441.

Campler, M. Jensen, M., Munksgaard, L. (2012) Lying and Feeding behaviour in Danish Holstein and Jersey Cows during the prepartum period. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Capellini, I., Barton, R.A., McNamara, P., Preston, B.T., Nunn, C.L. (2008) Phylogenetic analysis of the ecology and evolution of mammalian sleep. *Evolution*, 62, 1764-1775.

Cestari, A.,A., Fregonesi, J.A., Weary, D.M., Von Keyserlingk, M.A.G (2013) Motivation for access to pasture in dairy cows. In: Proceedings of the 47th International Congress of the ISAE, International Society for Applied Animal Behaviour Science, Florianoplois, Brazil, 2-6 June, pp.73.

Charlton, G., Rutter, M., East, M. And Sinclair, L. (2010) The effect of TMR on dairy cow preference to be indoors or at pasture. In: Proceedings of the 44th Congress of the International Society for Applied Ethology (ISAE) Swedish University of Agricultural Sciences, Uppsala, Sweden. 4-7 August 2010.

Charlton, G.L, Rutter, S.M., East, M. And Sinclair, L.A. (2011) Preference of dairy cows: indoor cubicle housing with access to a total mixed ration versus access to pasture. *Applied Animal Behaviour Science*, 130, 1-9.

Chapinal, N., Goldhawk,C., de Passille, A., von Keyserlingk, M., Weary, D., Rushen, J. (2010) Overnight access to pasture does not reduce milk production or feed intake in dairy cattle. *Livestock Science,* 129, 104-10.

DairyCo (2013a) Available at <http://www.dairyco.org.uk/technical-information/animal-health-welfare/lameness/husbandry-prevention/mobility-scoring/> Last accessed 06/08/13.

DairyCo (2013b) Available at: <http://www.dairyco.org.uk/technical-information/animal-health-welfare/mastitis/working-arena-prevention-of-infection/milking-parlour/liner-changes/>. Last accessed 06/08/13.

DairyCo (2013c) Available at <http://www.dairyco.org.uk/technical-information/animal-health-welfare/mastitis/5-point-plan-mastitis-prevention/> Last accessed 06/08/13.

DeLany, J. P. and West, D. B. (2000) Body Composition Changes and Conjugated Linoleic Acid. *Journal of the American College of Nutrition*, 19, 4875-4935.

DeVries, T.J., von Keyserlingk, M.A.G., Beauchemin, K.A., (2003). Diurnal feeding pattern in lactating dairy cows. *Journal of Dairy Science*, 86, 4079–4082.

DeVries, T.J., Aarnoudse, M.G., Barkema, H.W., Leslie, K.E., von Keyserlingk, M.A. (2012) Associations of dairy cow behavior, barn hygiene, cow hygiene, and risk of elevated somatic cell count. *Journal of Dairy Science*, 95, 5730-5739.

Dippel,S.,Tucker,C.B., Winckler,C. Weary, D.M. (2011) Effects of behaviour on the development of claw lesions in early lactation dairy cows. *Applied Animal Behaviour Science*, 134, 16-22.

DCWS (2012) Interactive Workshops: Cramer, G. And McDowell, G.A. Lameness Lesions and Management; Nash, C., Main, A., Villettaz Robichard, M., On-farm assessments to improve cow comfort, The First Dairy Cattle Welfare Symposium 23-26 October 2012, Guelph, Ontario, Canada.

Ellis, K. A., Innocent, G., Grove-White, D. , Cripps, P., McLean, W.G., Howard, C.V., Mihm, M. (2006). Comparing the Fatty Acid composition of Organic and Conventional Milk, Journal of Dairy Science. 89, 1938-1950.

EFSA (European Food Safety Authority) (2009a) Scientific report of EFSA prepared by the Animal Health and Welfare Units on the effect of farming systems on dairy cow welfare and disease. *Annex to the EFSA Journal* 1143, 1-284.

EFSA (European Food Safety Authority) (2009b) Scientific opinion of the panel on Animal Health and Welfare on a request from the European Commission on the welfare of cows. *The EFSA Journal* 1143, 1-38.

Esselemont, R.J., and Kossaibati, M.A. (1997) Culling in 50 dairy herds in England. Veterinary Record, 140: 36-39.

Fall, N., U. Emanuelson, K. Martinsson, and S. Jonsson (2008) Udder health at a Swedish research farm with both organic and conventional dairy cow management. *Preventative Veterinary Medicine*. 83, 186–195.

Falk, A.C.,Weary, D.M. Winckler, C.,von Keyserlingk, M.A. (2012). Preference for pasture versus freestall housing by dairy cattle when stall availability indoors is reduced. *Journal of Dairy Science*, 95, 6409-6415.

FAWC (Farm Animal Welfare Council) (2009) Dairy cow welfare: more needs to be done. In: News and reports, *The Veterinary Record* October 31, 2009.

FAWC (Farm Animal Welfare Council) (2010). Cows kept in very large herds can have lives worth living In: News and Reports, Veterinary Record, August 28, 2010. 313.

Fisher, A.D., Verkerk, G.A., Morrow, C.J. and Matthews, L.R. (2002) The effects of feed restriction and lying deprivation on pituitary-adrenal axis regulation in lactating cows. *Livestock Production Science*. 73, 255-263.

Fisher, A.D., Stewart, M., Verkerk, G.A. Morrow, C.J. and Matthews, L.R. (2003) The effects of surface type on lying behaviour and stress responses of dairy cows during periodic weather-induced removal from pasture*. Applied Animal Behaviour Science*. 81, 1-11.

Frankena, K., K. A. S. van Keulen, J. P. Noorhuizen, E. N. Noordhuizen-Stassen, J. Gundelach, D. J. de Jong, and I. Saedt. (1992) A cross-section study into prevalence and risk indicators of digital haemorrhages in female dairy calves. *Preventative Veterinary Medicine*. 14, 1–12.

Frelich, J. and Slachta, M. (2011) Impact of seasonal grazing on udder health of cows. *Acta Universitatis Agriculturae et silviculturae Mendelianae Brunensis* LIX: 53-58.

Geary, U., Lopez-Villalobos, N., Begley, N., McCoy, F., O'Brien, B., O'Grady, L. and Shalloo, L. (2012). Estimating the effect of mastitis on the profitability of Irish dairy farms. *Journal of Dairy Science,* 95, 3662–3673.

Green, M.J., Bradley, A.J., Medley, G.F., and Browne, W.J. (2007). Cow, Farm, and Management Factors During the Dry Period that Determine the Rate of Clinical Mastitis After Calving, *Journal of Dairy Science.* 90, 3764–3776.

Goldberg, J.J., Wildman, E.E., Pankey, J.W., Kunkel, J.R., Howard, D.B., and Murphy, B.M. (1992) The Influence of Intensively Managed Rotational Grazing, Traditional Continuous Grazing, and Confinement Housing on Bulk Tank Milk Quality and Udder Health. *Journal of Dairy Science*, 75, 96-104.

Hanna, A., Norell, L. and per Peetz, N. (2010) Temperature and humidity affects dairy cows' willingness to be on pasture. In: Proceedings of the 44th Congress of the International Society of Applied Ethology (ISAE) Swedish University of Agricultural Sciences, Uppsala, Sweden. 4-7 August 2010.

Haskell, M.J., Rennie, L.G., Bowell, V.A., Bell, M.J. and Lawrence, A.B. (2006). Housing System, Milk Production, and Zero-Grazing Effects on Lameness and Leg Injury in Dairy Cows. *Journal of Dairy Science*. 89, 4259–4266.

Haskell , M.J., Langford, M.F., Jack, M.C., Sherwood, L., Lawrence, A.B., and Rutherford, K.M.D. (2009). The effect of organic status and management practices on somatic cell counts on UK dairy farms *Journal of Dairy Science.* 92, 3775–3780.

Hernandez-Mendo, O., von Keyserlingk,M.A.G., Veira, D.M., and D. M. Weary. (2007). Effects of Pasture on Lameness in Dairy Cows. *Journal of Dairy Science*. 90, 1209–1214.

Hovi, M., and S. Roderick. (2000). Mastitis and mastitis control strategies in organic milk. *Cattle Practice.* 8, 259–264.

Hultgren, J., and Bergsten, C. (2001). Effects of a rubber-slatted flooring system on cleanliness and foot health in tied dairy cows. *Preventative Veterinary Medicine*. 52,75–89.

Husfeldt, A.W. and Endres, M. (2012) Dairy welfare when using recycled manure solids for bedding. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Huxley, J. And Green, M. (2010) More for less: dairy production in the 21st century. *Veterinary Record*. 712-713.

Huzzey, J.M., Veira, D.M., Weary, D.M., von Keyserlingk, M.A.G., (2007). Prepartum behavior and dry matter intake identify dairy cows at risk for metritis. *Journal of Dairy Science*. 90, 3220–3233.

Irrange, N. and Knierim, U. (2012) Can pasture access contribute to reduced agnostic interactions and relaxation in the loose housing barn in horned dairy cows? In: Proceedings of the 46th Congress of the International Society for Applied Ethology (ISAE) Vienna, Austria, 31 July- 4 August 2012.

Jacobs, J.A. Siegford, J. M. (2012) Invited review: The impact of automatic milking systems on dairy cow management, behavior, health, and welfare. Journal of Dairy Science, 95, 2227–2247.

Jensen, M.B., Munksgaard, L., Pedersen, L.J., Ladewig, J. And Matthews, L (2004) Prior deprivation and reward duration affect the demand function of rest in dairy heifers. *Applied Animal Behaviour Science*. 88, 1-11.

Ketelaar-de Lauwere, C.C., Ipema, A.H., van Ouwerkerk, E.N.J., Hendriks, M.M.W.B., Metz, J.H.M., Noordhuizen, J.P.T.M and Schouten, W.G.P (1999) Voluntary automatic milking in combination with grazing of dairy cows. Milking frequency and effects on behaviour. *Applied Animal Behaviour Science*. 64, 91-109.

Keyserlingk, M.A.G., Rushen, J., de Passille, A.M. and Weary, D.M. (2009) Invited review: The welfare of dairy cattle – key concepts and the role of science. *Journal of Dairy Science*, 92, 4101-4111.

Kilgour, R.J. (2012) In pursuit of "normal": a review of the behaviour of cattle at pasture. *Applied Animal Behaviour Science* 138, 1-11.

Krohn, C.C., Munksgaard, L. and Jonasen, B. (1992) behaviour of dairy cows kept in extensive (loose housing/pasture) or intensive (tie stall) environments 1. Experimental procedure, facilities, time budgets – diurnal and seasonal conditions. *Applied Animal Behaviour Science*, 34, 37-47.

Krohn, C.C. and Munksgaard, L. (1993) Behaviour of dairy cows kept in intensive (loose housing/pasture) or intensive (tie stall) environments. II. Lying and lying down behaviour. *Applied Animal Behaviour Science*, 37, 1-16.

Laven, R. (2012) Assessment of the Effect of Treatment with Long-Acting and Short Acting Non-Steroidals on the Pain Responses Associated with Lameness in Dairy Cattle. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Langford, F.M. and Stott, A.W. (2012). Culled early or culled late: economic decisions and risks to welfare in dairy cows. *Animal Welfare*, 21, 41-55.

Langford, F., Bell, D., Chumia, D., Grahama, R-L., Mhairi, J., Nevison, I., Roberts, D., Haskell, M. (2013). Housing type affects the lying behaviour of dairy cows given access to an outside loafing 'paddock'.In: Proceedings of the 47th International Congress of the ISAE, International Society for Applied Animal Behaviour Science, Florianoplois, Brazil, 2-6 June, pp.73.

Legrand, A.L., von Keyserlingk, M.A.G. and Weary, D. M. (2009) Preference and usage of pasture versus free-stall housing by lactating dairy cattle. *Journal of Dairy Science*. 92, 3651-3658.

Legrand, A., Schutz, K.E. and Tucker, C.B (2011) Using water to cool cattle: Behavioural and physiological changes associated with voluntary use of cow showers. *Journal of Dairy Science*, 94, 1-11.

Maynard, R. (2012) Role of Dairy Farmers of Canada in the development of an assessment program for the well-being of dairy animals. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Mattiauda, D.A., Tamminga, S., Gibb, M.J., Soca, P. Bentancur, O. Chilibroste, P. (2013) Restricting access time at pasture and time of grazing allocation for Holstein dairy cows: Ingestive behaviour, dry matter intake and milk production, *Livestock Science.* 152, 53-62.

Medrano-Galarza, C., Gibbons, J., Wagners, S., de Passillé, A.M., Rushen, J. (2012) Behavioural changes in dairy cows with mastitis. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Miller, K. and Wood-Gush, D.G.M (1991) Some effects of housing on the social behaviour of dairy cows. *Animal Production* 53, 271-278.

McConnel, C.S., Lombard, J.E., Wagner, B.A., and Garry, F.B. (2008). Evaluation of Factors Associated with Increased Dairy Cow Mortality on United States Dairy Operations *Journal of Dairy Science*. 91, 1423–1432.

Motupalli, P.R., Rutter, S.M., Bleach, E.C., Sinclair, L.A. (2013) Dairy heifer preference for being indoors or at pasture is affected by previous experience. In: Proceedings of the 47th International Congress of the ISAE, International Society for Applied Animal Behaviour Science, Florianoplois, Brazil, 2-6 June, pp.73.

Munksgaard,L. and Thomsen, P. (2012) Effects of Cow characteristics on lying behaviour and activity in Danish dairy herds with free stalls. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Nadis (2009) Lameness control in Dairy Herds. Available at <http://www.nadis.org.uk/pdfs/Foot%20Trimming.pdf> Last accessed 06/08/13.

Norring, M. And Valros, A. (2010) Milk yield affects time budget in dairy cows. In: Proceedings of the 44th International Congress of the International Society for Applied Ethology.

Offer, N.W. (2002) Effects of cutting and ensiling grass on levels of CLA in bovine milk. In: Gechie, L.M., Thomas, C.(eds.) Proceedings of the 13th International Silage Conference, Scottish Agricultural College, Auchincruive, UK, pp. 16–17.

O'Connell, J., Giller, P.S. and Meaney, W. (1989) A comparison of dairy cattle behavioural patterns at pasture and during confinement. *Irish Journal of Agricultural Research*. 28, 65-72.

O'Connell, J.M., Meaney, W.J., Giller, P.S., Collins, E. And Boon, C. (1993) Behavioural studies – their role in improving housing facilities for overwintering dairy cows. In: Proceedings of the American Society of Agricultural Engineers, St. Joseph, Michigan, USA. Livestock Environment IV. Coventry, UK 6-9 July 1993, 298-305

Onyiro, O.M., and Brotherstone, S. (2008). Genetic Analysis of Locomotion and Associated Conformation Traits of Holstein-Friesian Dairy Cows Managed in Different Housing Systems. *Journal of Dairy Science*. 91, 322–328.

Pinheiro Machado Filho, L., Carlos, P., Wickeart,C., Avila,L., Tais, S., Hotzel, M.J. (2012) Influence of social hierarchy on the use of shade by dairy cows. In: Proceedings of the 46th Congress of the International Society for Applied Ethology (ISAE) Vienna, Austria, 31 July-4 August 2012.

Phillips, C.J.C., Waita, J.M., Arney, D.R. and Chiy, P.C. (1999) The effects of sodium and potassium fertilizers on the grazing behaviour of dairy cows. *Applied Animal Behaviour Science*. 61, 201-213.

Regula, G., Danuser, J., Spycher, B. and Wechsler, B. (2004) health and welfare of dairy cows in different husbandry systems in Switzerland, *Preventative Veterinary Medicine,* 66, 201-213.

Regula, G., Danuser, J., Spycher, B. and Wechsler, B. (2004) Health and welfare of dairy cows in different husbandry systems in Switzerland. *Preventive Veterinary Medicine.* 66, 247-264

Roesch, M., Doherr, M.G., Scharen, W., Schallibaum, M., and Blum, J.W. (2007). Subclinical mastitis in dairy cows in Swiss organic and conventional production systems. *Journal of Dairy Research*. 74, 86–92.

Rushen, J. (2012) Assessment and guidelines for Dairy Cattle Welfare. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Santman-Berends, I.M.G.A., Olde Riekerink, R.G.M., Sampimon O.C., van Schaik G., and Lam T.J.G.M. (2012). Incidence of subclinical mastitis in Dutch dairy heifers in the first 100 days in lactation and associated risk factors. *Journal of Dairy Science.* 95, 2476-2484.

Sato, K., Bartlett, P.C., Erskine, R.J., and Kaneene. J.B. (2005). A comparison of production and management between Wisconsin organic and conventional dairy herds. *Livestock Production Science*. 93,105–115.

Siegford, J., Elischer, A., Karcher,E.(2012) Validating the Accuracy of Activity Monitor Data from Dairy Cows Housed in a Pasture-Based Automatic Milking System. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Schrer, T., and Pelzer A. (2006) What is the preferred lying down position of the dairy cow? Or: indoors is not the same as grassland. *Milchpraxis*, 44, 158-160.

Schütz, K.J.E., Cox, N.R. and Matthews, L.R. (2008) How important is shade to dairy cattle? Choice between shade or lying following different levels of lying deprivation. *Applied Animal Behaviour Science.* 114, 307-318.

Schütz, K., Clark, K., Cox, N., Matthews, L. and Tucker, C. (2010) Responses to short-term exposure to rain and wind by dairy cattle. In: Proceedings of the 44th Congress of the International Society for Applied Ethology (ISAE) Swedish University of Agricultural Sciences, Uppsala, Sweden 4-7 August 2010.

Schütz, K., Cox, N., Tucker, C. (2012) Cattle behavioural and physiological responses to the amount of shade in pasture-based dairy systems. In: Proceedings of the 46th Congress of the International Society for Applied Ethology (ISAE) Vienna, Austria, 31 July- 4 August 2012.

Singh, S.S., Ward, W.R., Lautenbach, K., Hughes, J.W. and Murray, R.D. (1993) Behaviour of first lactation and adult dairy cows while housed and at pasture and its relationship with sole lesions. *Veterinary record.* 133, 469-474.

Solano, J.Z.,Solano, L., Orsel, K., Pellerin, D., LeBlacn, S.DeVries, T. Gibbons, J., Haley, D. (2012) The Association between lying time and the prevalence of lameness in dairy cows housed in free-stall barns. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Soriano, F.D., Polan, C.E., Miller, C.N., (2001). Supplementing pasture to lactating Holsteins fed a total mixed ration diet. *Journal of Dairy Science*, 84, 2460–2468.

Somers, J.G.C.J., Frankena, K., Noordhuizen-Stassen, E.N., and Metz, J.H.M. (2003). Prevalence of claw disorders in Dutch dairy cows exposed to several floor systems. *Journal of Dairy Science*. 86, 2082–2093.

Spörndly, E., Wredle, E. (2004) Automatic milking and grazing—Effects of distance to pasture and level of supplements on milk yield and cow behavior. Journal of Dairy Science, 87, 1702–1712.

Steensels, M., Bahr, C., Berckmans, D., Halachmi, I., Antler, A. and Maltz, E. (2012) Lying patterns of high producing healthy dairy cows after calving in commercial herds as affected by age. *Applied Animal Behaviour Science*. 136, 88-95.

Thomsen, P.T., Kjeldsen, JA.M., Sørensen, T., and Houe, H. (2004) Mortality (including euthanasia) among Danish dairy cows (1990-2001). *Preventative veterinary medicine*. 62, 19-33.

Thomsen, P.T., Kjeldsen, JA.M., Sørensen, T., Houe, H., and Ersbøll, A.K. (2006) Herd-level risk factors for the mortality ofcows in Danish dairy herds. *Veterinary Record*. 158, 622-626.

Thomsen, P.T., and Sørensen, J.T. (2009) Factors affecting the risk of euthanasia for cows in Danish dairy herds. *Veterinary Record*. 165, 43-45.

Tucker, C.B., Ledgerwood, D. and Stull, C. (2010) Muddy conditions reduce lying time in cattle. In: Proceedings of the 44th Congress of the International Society of Applied Ethology (ISAE) Swedish University of Agricultural Sciences, Uppsala, Sweden. 4-7 August 2010.

van der Tol, P.P.J., Metz, J.H.M., Noordhuizen-Stassen, E.N., Back, W, Braam, C.R., and Weijs, W.A. (2005). Frictional forces required for unrestrained locomotion in dairy cattle. *Journal of Dairy Science*. 88, 615–624.

van Eerdenburg, F., Vázquez-Flores, S., Saltijeral-Oaxaca, J., Sossidou, E. (2012) Increasing milk yield using a cow comfort assessment system with variable weight for parameters depending on their score. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Vasseur, E. and Bergeron, R. (2012) Snowy days do not seem to bother cows in Ontario. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Wagner, Kathrin, Barth, K., Palme, R. Futschik, A., Waiblinger, I. (2012) Integration into the dairy cow herd: Long-term effects of mother contact during the first twelve weeks of life. *Applied Animal Behaviour Science.* 141, 117-29.

Walker, G. P., Dunshea, F. R. and Doyle, P. T. (2004) Effects of nutrition and management on the production and composition of milk fat and protein: a review, *Australian Journal of Agricultural Research,* 55, 1009-1028. Abstract available at <http://www.publish.csiro.au> Accessed 15/02.13.

Walker , M.D. Duggen, G., Roulston, N., Van Slack, A., Mason,G. (2012) Negative affective states and their effects on morbidity, mortality and longevity. *Animal Welfare.* 21, 497-509.

Watters, A., Meijer, K., Barkema, H., Leslie, K., von Keyserlingk, M., DeVries, T. (2012) Relationship between behavioural patterns and risk of elevated SCC in free-stall housed lactating dairy cows. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Webster, A. J. (2002). Effects of housing practices on the development of foot lesions in dairy heifers in early lactation. *Veterinary Record*. 152, 351–358.

Webster, S. (2012) Data on production systems and health for the EU dairy industry. A report for Compassion in World Farming, Godalming, Surrey, UK.

Weary, D., Schuppli, C., Ventura, B., Spooner, J., von Keyserlingk, M. (2012) Attitudes to Contentious Practices in Dairy Farming. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Whay, B. (2012) Management of Lameness and Other Health problems for Dairy Cattle Welfare. The First Dairy Cattle Welfare Symposium, 23-26 October 2012, Guelph, Ontario, Canada.

Whitaker, D.A., Kelly, J.M., and Smith, S. (2000). Disposal and disease rates in 340 British dairy herds. Vet Rec 146: 363-367.

White, S. L., Bertrand, J. A., Wade, M. R. et al (2001) Comparison of Fatty Acid Content of Milk from Jersey and Holstein Cows Consuming Pasture or a Total Mixed Ration, *Journal of Dairy Science.* 84, 2295-2301.

Winkler, B. and Margerison, J.K. (2012) Mechanical properties of the bovine claw horn during lactation. Journal of Dairy Science. 95, 1714-1728

Wiktorsson, H. And Sporndly, E. (2002) Grazing: an animal welfare issue for automatic milking farms. In: The First North American Conference on Robotic Milking. Plenary VI. 32-43.

Wredle, E., L. Munksgaard, and E. Spörndly. (2006). Training cows to approach the milking unit in response to acoustic signals in an automatic milking system during the grazing season. *Applied Animal Behaviour Science*, 101, 27–39.