Main causes of poor welfare in intensively reared dairy cows

Fabio Abeni¹, Giuseppe Bertoni²

¹Centro di Ricerca per le Produzioni Foraggere e Lattiero Casearie. Cremona, Italy
²Istituto di Zootecnica. Università Cattolica del Sacro Cuore, Piacenza, Italy

Corresponding author: Dr. Fabio Abeni. CRA-FLC Centro di Ricerca per le Produzioni Foraggere e Lattiero-Casearie, Sede distaccata di Cremona. Via Porcellasco 7, 26100 Cremona, Italy - Tel. +39 0372 433029 - Fax: +39 0372 435056 - Email: fabiopalmiro.abeni@entecca.it

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ABSTRACT

The aim of this review is to summarise the main causes of poor welfare in intensively reared dairy cows. Intensive farming systems are considered, both from a structural and a managerial point of view, for their constraints that may limit animal welfare: possible physical activity; acceptable interactions with humans and other animals; feeding and watering, protection from climate, parasites, and diseases. The dairy farms managed according to the organic rules do not always guarantee, per se, better welfare conditions; organic or low input dairy farming needs to consider the right interaction among cattle breed and herd management, focusing on the actual quality of feedstuffs meet face cow requirements.

The considered structural aspects evidence how special care must be given to the rest area (straw yard or cubicle); to the floors that should be not too hard or abrasive and not slippery; to the cubicle bedding material to ensure hygiene, softness, and dryness; to the feeding (and watering) area to reduce conflicts; to a microclimate control system, to avoid heat stress during summer time.

The importance of proper management for animal welfare is evidenced for buildings and equipment, to have clean and comfortable stables and well functioning milking machines; nutritive and storage quality of feeds; diet suitability (energy, protein, physically efficient fibre, buffers etc.), in the different phases of a dairy cow’s life (dry period, close-up, transition, and lactation); feed distribution (frequency and time), and 24h availability.

Special attention has to be paid to the social aspects, regarding both animal competition (stocking density, group size), and human/animal interactions (methods of management and manipulation).

The interaction between welfare and health requires special attention. Poor welfare can cause immune depression, thus increasing the risk of disease. In turn, any disease that causes an inflammatory response may determine depression, anorexia, an increase in temperature, and metabolic pathways deviation, with a worsening of the overall sense of well-being.

Key words: Welfare, Dairy cow, Management, Housing.

RIASSUNTO

PRINCIPALI CAUSE DI SCARSO BENESSERE NELL’ALLEVAMENTO INTENSIVO DELLA VACCA DA LATTE

Lo scopo di questa rassegna è quello di riassumere le principali cause di scarso benessere per le bovine da latte in allevamenti intensivi. I sistemi aziendali intensivi sono considerati nei loro aspetti strutturali e ge-
stionali che possono limitare le condizioni di benessere degli animali: possibilità di attività fisica; interazioni accettabili tra gli animali e con l’uomo; alimentazione e disponibilità di acqua di abbeverata; protezione dal clima, dai parassiti e dalle malattie. Le aziende da latte gestite secondo i protocolli della zootecnia organica (o biologica) non garantiscono sempre, per se, migliori condizioni di benessere; le aziende organiche (o biologiche) o quelle a bassa intensificazione produttiva devono considerare le giuste interazioni tra la razza allevata ed il tipo di gestione cui è sottoposta, con particolare attenzione alla reale disponibilità quantitativa e qualitativa dei foraggi e concentrati disponibili per coprire i fabbisogni nutritivi.
Gli aspetti strutturali considerati evidenziano come sia necessario porre particolare attenzione a: area di riposo (lettiera o cuccetta); pavimentazione, che non deve essere dura e scivolosa; materiale di fondo della cuccetta, per assicurare igiene, morbidezza e asciutto; area di alimentazione ed abbeverata, per ridurre i conflitti tra animali; sistema di controllo del microclima, per evitare stress da caldo durante il periodo estivo.
Si evidenzia l’importanza, per il benessere animale, di una corretta gestione delle strutture e degli impianti, per avere: stalle pulite e comode ed impianti di mungitura ben funzionanti; idonee qualità nutritive e di conservazione degli alimenti per il bestiame; diete adeguate (energia, proteina, fibra fisicamente efficace, tamponi, ecc.), nelle diverse fasi di vita della bovina (asciutta, preparazione al parto, transizione e lattazione); idonea distribuzione (frequenza e momento) dell’alimento e disponibilità dello stesso nelle 24 ore.
Attenzione particolare deve essere posta agli aspetti sociali, sia quelli relativi alla competizione tra animali (densità di allevamento, numerosità e gestione del gruppo), sia quelli relativi alle interazioni con l’uomo. Particolare attenzione è necessaria per le possibili interazioni tra benessere animale e salute. Sitiuazioni di scarso benessere possono provocare depressione del sistema immunitario, con conseguente rischio di malattia. Peraltro, ogni malattia che causa risposta infiammatoria può determinare depressione, anoressia, ipertermia e deviazione di vie metaboliche, con conseguente peggioramento delle sensazioni dell’animale.

Parole chiave: Benessere, Vacca da latte, Gestione, Edifici.

Introduction

Regarding animal welfare, the dairy cow is actually the least legislated animal industry in European Union. However, the knowledge regarding the factors that can affect cow welfare may represent a real opportunity to improve farm efficiency (Trevisi et al., 2006) in line with the ethical aspects discussed by Bertoni et al. (2007).

In the present paper, we consider only the main causes of poor animal welfare in intensively managed dairy farms which represent the majority in Italy. They will be presented and discussed in relation with the kind of factors which may generate the unpleasant situations for the animal, as well as negative consequences on milk yield and quality, on health or tissue damage, on fertility and longevity, and perhaps on their behaviour.

Farming systems

First of all, it is important to bear in mind that intensive breeding system cannot be considered a priori worse than the extensive system. For many people, the image of freely grazing animals is considered the maximum of welfare, but only a small part of the 5 freedoms (e.g. natural behaviour and activities). On the contrary, the widespread availability of fresh grass is limited to certain seasons (Bertoni et al., 1991), water is often found with difficulty, parasites and fears are a high risk, while climate excesses (cold, rain or heat) occur quite frequently.

Therefore, the real meaning of natural freedoms (at least for domestic animals: farm or pets) has to be reconsidered, as does the question whether a good intensive breeding situation - which should include some seasonal pasture, with its balance of pros
and cons - can be at least comparable to the wildness, particularly for animals selected for centuries to be suitable for indoor life.

**High milk yield and welfare**

As previously suggested, intensive dairy farms have several peculiarities. Some of them can improve the management of cows but they can also be causes of reduced levels of welfare, particularly as respects the continuous genetic increase in milk yield levels. A close negative relationship between genetic merit increase and fertility reduction have been emphasised (Butler, 1998; Webb et al., 1999; Lucy, 2001, 2003; Santos, 2001; Webb et al., 2004; Oltenacu and Algers, 2005); moreover, according to Smith et al. (2000), high producing herds report more cows being withdrawn due reproduction problems, mastitis, feet and leg diseases (hence reduced levels of welfare). Using reproduction as a case study, a possible explanation could be a genetic antagonism between milk yield and fertility, more likely due to a pleiotropic gene effect (Veerkamp et al., 2003); nevertheless, Hansen (2000) suggests that genetic control of fertility is low, while environmental factors are numerous and significant. Therefore, it can be inferred that high yielding dairy cows are fertile per se and that the likely existing genetic antagonism between milk yield and reproduction is not the only factor in low fertility. When milk yield is increased, it becomes increasingly difficult, particularly in poorly managed farms, to satisfy the energy (and protein) requirements of cows which genetically direct nutrients toward the mammary glands (Verkaamp et al., 2003). Thus, they become more susceptible to metabolic stress and consequently to metabolic and/or infectious diseases, as well as to reproductive problems (Garnsworthy and Webb, 1999; Knight et al., 1999; Ward and Parker, 1999). This therefore suggests a higher risk for cows with an unsatisfactory supply of nutrients and a reduced efficiency of reproductive apparatus and the immune system (Ferguson, 1991; Schukken et al., 1999). This can explain the higher frequency of infectious problems regarding the reproductive apparatus (Heuer et al., 1999), as well as other diseases, infectious or metabolic issues with more or less dramatic consequences, such as liver triglyceride accumulation, impaired fertility and increased culling (Bertoni et al., 2004).

It can therefore be inferred that high milk yield is an important predisposing factor to health disorders and fertility reduction, as suggested by Oltenacu and Algers (2005). Nevertheless, the high variability among dairy farms (Stevenson, 1999), as well as within the cows of the same farm (Bertoni et al., 2008), suggests the possibility of improvement. According to the above references, the most promising aspects seem to be those regarding the effects of negative energy balance (NEB; Veerkamp et al., 2003) on both oestrus resumption after calving (Butler, 1998) and conception rate, but also the effects of “diseases” in the early lactation (Roche et al., 2000). For both aspects, it appears obvious to us that either the long term genetic selection for better fitness and tolerance to metabolic stress (Oltenacu and Algers, 2005) and the improvement of breeding management (Drackley, 2006) could be essential in maintaining acceptable levels of health and fertility - hence of welfare - in high yielding cows. In fact, a recent paper by one of the authors suggests how better management may improve some reproductive aspects, in addition to BCS, health conditions and - what is more surprising - milk yield (from 20.12 to 25.17 kg/d) (Treviši et al., 2006). This could confirm that the difficulty for the cow to cope with the gap between nutrient output and input does not
necessarily depend on the genetic selection alone (Knight et al., 1999; Nielsen, 1999).

**Organic systems**

An emerging issue in Italy (as in the other Western countries) is represented by the attempts to match the increased public demand of “sustainable” agricultural systems. In several countries, consumers perceive organic farming products as more “animal and environment friendly” than conventional products (Lund and Algers, 2003). Generally, organic dairy farms have lower milk production than conventional farms (Hovi et al., 2003; Roesch et al., 2005), as a consequence of a reduced amount of concentrates and protein supplements in the former (Roesch et al., 2005). Therefore, it has been suggested that organic dairy cows with high genetic potential for milk production may be at risk for energy deficiency in early lactation and may suffer from metabolic disorders and poor fertility (Hovi et al., 2003). This observation is obvious because in these high genetic merit animals, the milk yield reduction is lower with respect to possible nutrient deficiency; furthermore, this seems confirmed by Reksen et al. (1999), who reported results that organically managed dairy cows showed impaired reproductive efficiency compared with those under conventional management, when adjusted for milk yield, breeding season, service, and parity. However, from a metabolic point of view, Roesch et al. (2005) reported no difference between organic and integrated production in various blood measures. Another real issue in organic farming - which requires some pasture feeding - is represented by some intestinal parasites (Lund and Algers, 2003); namely, alternative control strategies are required to guarantee a sustainable balance between the most common parasites and the stock under organic management (Hovi et al., 2003). Therefore, it appears wise to utilise breeds more adapted to pasture and less intensive conditions for this kind of breeding system. However, a different degree of intensification is possible in organic farming for animal production and according to the genetic trait of bred animals.

**Intensive systems**

To achieve the best level of comfort in the intensive systems, facility design and management should be based on knowledge of animal physiology, animal behaviour and animal needs (which depend on their genetic traits). In other words, keeping the five freedoms in mind, the life conditions would ensure the following:
- a very low effect of climate issues (cold, heat, rain, wind, solar exposure etc.);
- appropriate conditions minimizing trauma, lesions and disease outbreaks;
- optimal availability of water and diets; the latter based on wholesome feeds and well balanced rations to cover the specific requirements;
- an acceptable display of natural behaviour (movement, heat symptoms, social relationships, animal-human relationships etc.) to reduce any cause of suffering as much as possible.

*Building for cow comfort: resting area, bedding materials, floors, feeding area, microclimate control, and automation*

*Resting area - The first step in a housing project for dairy cows is the choice of bedding system - straw yard (SY) or cubicle - and the absence or presence of grazing. In fact, the resting area must provide a clean, dry and comfortable bed and should be the most comfortable place for the cow to lie down. Many benefits may derive from this issue: first as respects animal welfare, and, as a consequence, livestock production.*
Blood flow to the udder increases by about 50% when a cow is lying down (Rulquin and Caudal, 1992). Blood flow to the udder is directly proportional to milk production. Examining the available literature, Grant (2004) speculated that 1 additional hour lying time beyond 7 h/d is associated with 1 kg/cow/d more milk. These choices regarding resting area may affect cow welfare first by behavioural modifications, and successively by anatomical injuries and health problems (locomotion and udder). Generally, cows in the SY system have a significantly greater lying time, ruminating time and synchronisation of lying behaviour than in the cubicle system (Fregonesi and Leaver, 2001). However, the cows are significantly cleaner in the cubicle system, even though milk production, cell count or locomotion score are not necessarily affected (Fregonesi and Leaver, 2001). In cubicles, agonistic interactions are greater and the diurnal pattern of lying is disrupted, especially for high yielding cows when the number of cubicles is lower than the number of cows (Fregonesi and Leaver, 2002). As recently confirmed by Haskell et al. (2006), there are more lame cows on zero-grazing farms (39±0.02%) than on grazing farms (15±0.01%), and lameness scores were higher (worse) on cubicle farms compared with SY farms (0.25±0.01 vs 0.05±0.01; in a 0=“sound” and 1=“lame” binary trait).

In fact, cows in SY had by far the lowest number of claw disorders; over 80% of cows exposed to concrete flooring had at least one claw disorder at the time of observation, whereas on SY surfaces, this percentage was between 55 and 60 (Somers et al., 2003).

Bedding materials - The wide diffusion of barns with cubicles among countries (i.e., different latitude, environment, climate) has indicated the importance of the bedding material. This choice - also part of the housing system - may affect several aspects of animal welfare: cubic usage; hock lesions; hygiene in the barn and during milking, related to udder health. For example, comparing sawdust, geotextile mattress, and sand as cubicle bedding materials, Tucker et al. (2003) showed how mattresses are less preferred and, in our opinion, this result confirms the suggestion from a Canadian survey (Weary and Taszkun, 2000), where mattresses were related to a higher prevalence of hock lesions. However, a seasonal influence on cow preference must be considered, in the Italian climate, as evidenced in the work of De Palo et al. (2006). They reported the results of a preference test for lying, which showed that cows preferred cubicle floors with polyethylene vinyl acetate mats over those with polypropylene vinyl acetate mats, wood shavings or solid manure; nevertheless, under conditions of heat stress, with a temperature-humidity index >80, their first choice was wood shavings and solid manure lying areas (De Palo et al., 2006). More recently, a comparison between straw and sand as bedding in cubicles showed that straw increased the time that cows spend lying, suggesting how cows preferred straw cubicles to sand cubicles. Sand cubicles were advantageous for cow cleanliness and health; in fact, hock lesions and claw diseases healed more quickly for cows using sand cubicles compared with straw (Norring et al., 2008). Cubicle surface and design, with associated aberrant cubicle use behaviour (including increased standing time in the cubicle, as reported in Table 1), have been suggested as risk factors for the development of lameness (Cook et al., 2004a). Reduced daily lying times, increased total standing time on hard surfaces, and ‘perching’ with the 2 front feet on the cubicle platform and the rear 2 feet in the alley are behaviours that have been associated with increased rates of lameness (Cook et al., 2004a). Therefore, cubicle bedding materials may affect preva-
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Table 1. Differences in stall usage of dairy cows with different lameness severity when sand or mattress are used as bedding material (adapted from Cook et al., 2004a).

|                            | Sand   | Mattresses |
|---------------------------|--------|------------|
| Prevalence of clinical lameness | %      |            |
| Differences in standing time in the stall: |        |            |
| Cows not lame              | h d⁻¹  | + 0.73     |
| Cows slightly lame         |        | + 2.32     |
| Cows moderately lame       |        | + 4.31     |

Barn floors - The choice of flooring surface must be made considering manure management, but also some important issues of animal health and welfare. Concrete is a popular flooring surface in dairy barns, likely due to its durability, availability, cost, and ease of cleaning, but it may predispose dairy cattle to lameness (Fregonesi et al., 2004). According to Tyson (2004), floor surfaces need to be smooth but rough, which means to ensure traction for the feet, but not sharp edges that could damage them. Grooving concrete is the common answer, but rubber belts (placed on the floor) can relieve some negative effects of concrete hardness, abrasiveness and slipperiness (Telezhenko et al., 2007).
These aspects must also be considered for areas like those in front of the parlour holding area and feed bunk (Tucker et al., 2006), where cow comfort may affect feeding behaviour and, as consequence, dry matter intake (DMI).

As mentioned before, the frictional properties of the floor surface must also be considered because they can affect cow gait features. Immediately, the cow modifies its gait according to the floor, for example, with quick walk and frequent short steps when the coefficient of friction \( \mu \) is <0.4 (Phillips and Morris, 2001). In the long term, consequences on claw health must be considered.

**Feeding and watering area** - Generally, feeding areas are places where competition among subjects can occur. Therefore, feed bunk barrier design and feeding space may play an important role in reducing conflicts. It is of great importance to consider the feeding space of not less than 60-61 cm/head (DeVries and von Keyserlingk, 2004), and the feed barrier design (Endres et al., 2005; DeVries and von Keyserlingk, 2006; Huzzey et al., 2006), because they can affect feeding behaviour. In particular, subordinate cows - as well as primiparous cows (Bach et al., 2006) - may be negatively affected in their feeding behaviour when feed bunk barrier design and feeding space are below their optimal values. Avoiding overstocking at the feed bunk can help to increase feeding activity and to reduce competition. Finally, the use of a barrier that provides some physical separation between adjacent cows, such as a headlock feed barrier, can be useful to further reduce competition at the feed bunk (Huzzey et al., 2006). As a result, overstocking can negatively affect both resting and feeding behaviours which may lead, as a consequence, to increased chronic stress and reduced feed intake (Grant and Albright, 2001).

Water availability is also important and, in cubicle barns equipped with basins, 5 cm of basin front per cow and at least two water stations per group must be provided. Access to these basins should be easy, while a minimum beam of 3.65 m of space around the watering station must be allowed to avoid stressful interactions among cows, reduced water intake and, as a consequence, decreased DMI.

**Microclimate control** - The housing system may affect the microclimate to which cows will be exposed. The main microclimate problem in dairy cow housing in Italy is related to the summer season, when heat stress can negatively affect cow welfare (Calamari and Mariani, 1998; Abeni et al., 2007; Calamari et al., 2007). Dairy cow housing can negatively affect cow welfare in the summer season when no shade is available (even just from trees), the barn is not correctly oriented, building materials have high thermal conductivity, barn indoor volume is too small or there is poor natural ventilation that is not compensated by a fan system. The consequences of heat stress on...
cow welfare start when the first behavioural response - the search for a shaded and comfortable place - is not successful. As observed by Bertoni et al. (2003), the metabolic and endocrine changes that take place are a lower blood flow rate in the digestive tract, a reduction in both gut motility (slower digesta flow rate) and chewing activity. These changes, as well as the feed intake reduction, both subsequent to heat stress, justify an increase in retention time and, as a consequence, an increase in digestibility; however, at the same time, DMI can be noticeably reduced. At the same time, in the heat stressed animal, fermentations can be modified towards an exaggerated acid production, as a result of the lower fibre intake, the increased rumen retention time and the reduced saliva secretion accompanying the reduced chewing activity (Bertoni et al., 2003). These modifications contribute to the changes in nutrients partitioning, which is the cause of some important variations in milk quality; among them, of particular interest for cheese production are decreased milk protein content; worsening of cheesemaking characteristics such as titratable acidity and rennet coagulation (Calamari and Mariani, 1998). To reduce heat stress problems, natural ventilation can be used, namely, with high eaves, open sides with curtains, and an open ridge. Quite often, mechanical ventilation using fans and inlets is otherwise needed. No matter the type, a ventilation system requires constant management and adjustment, because it is the environment in which the cow works her 24-hour a day shift. While automatic controls can be used to do the minute-to-minute adjustment of the mechanical system, a skilled person must set those controls to insure cow comfort.

Automation - A last point about housing systems should be represented by the introduction of automation in dairy herd management. A good example is that of the automatic milking systems. When an innovation of this type is implemented in a dairy farm, different aspects of animal welfare can be affected. In the automatic milking systems, the cow must voluntarily go to the milking unit; this implies considering if the barn layout can help this kind of behaviour, and if the system has critical points which can increase the number of conflicts among cows. In the available results from an automatic milking trial involving primiparous cows, we observed a trend for slightly increased plasma cortisol level in cows in the automatic milking system, when compared with cows in a traditional milking parlour system (Abeni et al., 2005). As recently reviewed by Svennersten-Sjauja and Pettersson (2008), one of the main issues concerning animal welfare in automatic milking systems is the disruption of cow’s synchronous activity, typical of social animals like cattle. In fact, in automatic milking systems, they are forced to carry out eating, milking, and resting activity separately and line up in front of the milking unit to be milked individually (Svennersten-Sjauja and Pettersson, 2008).

A look at dairy housing facilities in Italy
Finally, to describe the Italian situation of an intensive dairy region, we report the main results from a field survey in Lombardia (Campiotti, 2003). Table 2 summarises some practical suggestions for dairy housing facilities to match cow welfare in intensive farming systems, and it shows the results from the survey, where the stables have been compared with the goals of each item (Campiotti, 2003).

Maintenance and management
To build a good housing system, as previously described, it is necessary to ensure
animal welfare, but this could be insufficient. To guarantee the welfare potentiality, housing, facilities and equipment need to be properly maintained (e.g. surfaces must be cleaned; facilities and equipment must be periodically checked, repaired, or substituted). Additionally, even in a good environment, cows have to be adequately managed and fed, according to their physiological stage.

**Buildings and equipment**

Once a housing system is built, a good management for proper maintenance must then be adopted. A major issue regards the floor cleaning system and frequency. In fact, when the floor is covered with slurry, the dynamic of the cow’s gait is affected, and this may lead to a reduction in its walking activity (Phillips and Morris, 2000), with negative consequences on cow health, feeding behaviour and feed intake and, as a consequence, on milk production.

The cubicle maintenance is also important because it must provide a clean, dry and comfortable bed and should be the most comfortable place for the cow to lie down. On the contrary, when the bed is lacking and the depth below the curb is excessive, the cow decreases the lying time, mainly by a reduction of the average bout duration (Drissler et al., 2005). Throughout the day and in the long run, this could mean a reduced and, perhaps, insufficient lying time. The consequences of poor welfare related to

### Table 2. Housing items and behavioural features linked to dairy cow welfare (adapted from Campiotti, 2003).

| Items                  | Units | Mean values from Lombardia survey | Goals      |
|------------------------|-------|-----------------------------------|------------|
| **Facility ergonomy**  |       |                                   |            |
| Feeding lane width     | m     | 4.0                               | ≥4.0       |
| Passage lane width     | "     | 2.0                               | ≥3.7       |
| Stall width            | cm    | 120                               | 114-122    |
| Educator height        | "     | 106                               | 115-120    |
| **Overcrowding indexes** |       |                                   |            |
| Stalls per cow         | n/cow | 0.97                              | ≥0.95      |
| Feeding-gate positions | "     | 0.91                              | ≥0.75      |
| Drinking space availability | cm/cow | 4.0                           | 7.5        |
| " " " " at the exit of milking parlour | " | 30                                 | 60         |
| Waiting time before milking | min | 63                                 | <60        |

| **Behavioural indexes** | | | |
| Stall usage (lying cows) related to cows not at the feeding-gate or that are drinking | % | 82 | ≥90 |
| Standing cows related to cows not at the feeding-gate or that are drinking | " | 15 | ≤5 |
| Ruminating cows in the stalls related to cows that are lying in the stalls | " | 62 | ≥65 |
uncomfortable housing may also affect the last trimester of gestation, because lying time in that period is an important issue for the uterine blood flow, which may affect the health of the future newborn (Nishida et al., 2004). Furthermore, according to Fulwider et al. (2007), adding bedding material several times per week may reduce the incidence of skin lesions.

Nevertheless, during daily herd management, individual cows are often temporarily deprived of the opportunity to lie down while waiting for veterinary or reproductive procedures. The need to reduce the time of lying deprivation has been emphasised by Cooper et al. (2007), describing an alteration of cow behaviour as a consequence of different duration of this deprivation (Figure 2).

A further very important issue for dairy cow welfare is represented by proper maintenance of the milking equipment. In fact, according with Rasmussen and Madsen (2000), there are 5 mechanisms by which the milking machine can affect udder health:

1) contamination of the teat skin;
2) change of teat condition;
3) cause bacteria to penetrate the teat canal;
4) spread of bacteria in the area;
5) variable emptying of the udder.

The first (negative) result may be a new bacterial infection in the udder. All these factors can be more or less avoided or improved by optimal machine functioning and by a proper milking routine.

**Feed quality**

The nutritive status of the cow is a key issue in its welfare. A good diet, obtained with high quality feeds, is a critical issue in dairy cow management. The first aspect is the chemical composition of the feed which, of course, affects its nutritive value. Among the analytical features, the NDF content may represent a limiting factor with respect to digestibility and in meeting the desired intake of the diets, but it is also related to the requirement of a minimum amount of fibre with sufficient structural properties (due to particle size and defined physically effective fibre). It allows adequate stimulation of salivary flow and rumen motility to maintain optimal digestive conditions (Stone, 2004). The second, but not less important, aspect is the storage quality of the feeds. The main enemies on dairy farms are moulds and mycotoxins from grain and toxic products; for example, bad quality silages (Fromageot, 1978; Howie, 1988). These toxins may affect animal growth, development, fertility, and health (Coulombe, 1993).

Another issue that is not always carefully considered is grazing. Although it seems obvious, we must emphasise that grazed forage is not a fully controlled feed. The main hazard in grazing systems is represented by parasites. Gastrointestinal helminths are ubiquitous parasites of grazing ruminants and cause decreases in survival, live-weight gain, milk production and reproduction performance (Holmes, 1993). The nutritional status of the host can influence the pathogenesis of parasitic infections and it is generally accepted that well-nourished animals withstand parasitism better than those less adequately fed (Holmes, 1993).

**Diet formulation and nutrient supply**

The most crucial stage for a dairy cow is represented by the transition from the dry period to the freshening and beginning of lactation. Field results support the strategy of 2 feeding groups within dry cows to minimize overfeeding of nutrients during the early dry period, but to slightly increase nutrient supply during the late dry period in order to facilitate anatomical and metabolic adaptation to lactation (Overton and Waldron, 2004). Among the nutritional-related metabolic aspects of the transition period,
Figure 2. Behaviours of lactating dairy cows (Adapted from Cooper et al. 2007).

(A), leg stomping = lifting hoof and replacing in same area without forward movement; (B), repositioning = moving all 4 legs slowly forward one at a time in a synchronised manner covering less than 1 body length in distance; (C), weight shifting = displacing weight from one side of the body to the other by either relaxing one leg or shuffling the legs) in response to different lying time deprivation: no deprivation (Control), 2 hours (2-h), and 4 hours (4-h).
the mineral balance of the dry cow diet can widely affect welfare, particularly through its effects on Ca availability. Low plasma level of Ca is related to milk fever, but it can cause a host of metabolic problems in fresh cows (e.g., retained placenta, slower uterine involution, greater uterine infection, poor feed intake, and abomasal displacement), as reported by Beede (1997). Diets for dry cows with relatively low intakes of Ca, P and K and with relatively high intakes of Mg and S have been suggested to prevent Ca metabolism failures (Lean et al., 2006). In some conditions, the same preventive effect can be obtained with a reduction in dietary anion-cation difference (Charbonneau et al., 2006).

An emerging area within transition cow metabolism and management is the consideration of interrelationships with the immune system. During their metabolic transition from late pregnancy to early lactation, dairy cows undergo a period of reduced immunological capacity during the periparturient period. The consequence of immunosuppression is that cows may be more susceptible to pathogens and diseases, particularly mastitis during the periparturient period (Overton and Waldron, 2004). While hypoglycaemia alone is not likely to exacerbate periparturient immunosuppression, hyperketonemia appears to have multiple negative effects on aspects of immune function (Overton and Waldron, 2004). Therefore, a prolonged energy deficiency in the first part of lactation or any factor exacerbating lipolysis at calving time, being cause of ketosis, can have a negative effect on immune function and may be related to the impact of fatty liver (Bertoni, 1996), which in turn can impair the immune function (Overton and Waldron, 2004).

The welfare of dairy cows may be affected by the physical features of the diet; when particle size is too small, the negative outcomes are reduced rumination activity, which implies altered rumen fermentations and pH. Nevertheless, it must be considered that intensively managed dairy cows, having no choice among differently located feedstuffs, try to choose, if possible, among particles of the total mixed ration. From the research of Leonardi et al. (2005), cows sort out long particles in favour of shorter particles. Adding water to dry diets reduced sorting and tended to increase neutral detergent fibre (NDF) intake and milk fat percentage (Leonardi et al., 2005). The same occurs for overly fermentable diets and in both cases the incidence of subacute ruminal acidosis is raised, with further negative consequences on laminitis and claw lesions (Nocek, 1997; Cook et al., 2004b) as well as on welfare. All these digestive disorders, which can be also attributed to problems of the large intestine (Bertoni et al., 1989; Bertoni and Trevisi, 1997), may permit the release and absorption of toxic substances (i.e. endotoxins as suggested by Gozho et al., 2005) and/or bacteria (Rowlands and Gardiner, 1998) that can induce inflammatory or infectious problems, with all the consequences which will be described for the disease stress.

In addition to some mistakes in diet formulation, the above described disorders - as well as deficiencies – can be due to many stress conditions (Hutcheson, 1992). It is well known that distress affects the appearance of stomach ulcers, namely in pigs (Mormède and Dantzer, 1988) and veal calves (Wiepkema, 1987). Furthermore poor welfare (or many considerable stress conditions) can modify the digestive channel physiology causing diarrhoea, abdominal pain and vomiting through different mechanisms (Gué, 1988). It is therefore highly possible that sudden stress conditions can modify the flow rate of digesta and then trigger some abnormal fermentation, particularly in the large intestine if an excessive amount of escaping
Causes of poor welfare in dairy cows

Rumen material reaches it. Many negative effects, including secondary “disease stress,” due to the endotoxins released by the bacteria (when pH is low), may take over (Bertoni et al., 1989). A similar suggestion has been formulated by Galyean and Eng (1998) with regard to the complex aetiology of metabolic disorders in feedlot cattle. As shown in the Figure 3, besides the well known components (i.e. diet type and microbial population), there are other aspects, such as patterns of social behaviour that may affect eating patterns and the incidence of digestive and metabolic disorders.

Feed distribution

Feeding is a predominant drive in dairy cattle and, consequently, any attempt to predict cow response to a particular environment must accurately describe feeding response (Grant, 2006). This means knowing the feeding behaviour (n° of meals, their length, daily-nightly distribution) but also DMI and, furthermore, the consequences on digestive function: rumen and intestine processes, rumination activity, faeces traits etc. In addition to feeds and diets, feed distribution timing has been identified as an important management tool. Cows subjected

Figure 3. Possible factors and interrelationships among factors affecting metabolic disorders in feedlot cattle. Solid arrows indicate relationships known to exist with a high degree of confidence; whereas dotted arrows represent putative relationships (adapted from Galyean and Eng, 1998).
to higher feed availability had, during the night, longer and larger meals and higher DMI (Calamari et al., 2006). This suggests that good feeding management can favour uniform feed intake during the day, avoiding an excessive reduction of intake during the night (Calamari et al., 2006).

The choice of the time of feed delivery may also improve feeding behaviour; DeVries and von Keyserlingk (2005) found a 12.5% increase in total daily feeding time of the cows when fed 6 h after milking. Nevertheless, the feed delivery 6 h after milking did not change the daily lying time of the cows, but decreased the latency to lie down after milking by 20 min (DeVries and von Keyserlingk, 2005), with increased risks for environmental mastitis.

Feeding frequency may directly affect the time budget of the cows thereby interfering with the possibility of the animal to rest. In fact, frequently fed (4 times/d) cows spent less time feeding in the morning and more in the evening and had less circadian variation in sleeping and lying ruminating, with milk yield reduction compared with cows fed less frequently (Phillips and Rind, 2001). According to Grant (2006), the top 10% of cows giving higher milk production have a resting time of 14.1 vs 11.8 h/d and the difference regards time standing in the alleys (1.1 vs 2.2 h/d) and perching in cubicles (0.5 vs 1.4 h/d). It is therefore important to reduce as much as possible any operation resulting in disturbance of the cow resting pattern.

Social aspects

Between cows

Social aspects may be very important in daily management of dairy herds, with special emphasis on the groups. A useful tool to assist with proper grouping decisions would need to consider competition for resources, stocking density, group size and composition (especially commingling of primi- and multiparous cows), and degree of commingling and movement between groups, particularly during the transition period when feeding behaviour is naturally depressed (Grant, 2006). A key issue is represented by the introduction of the freshening heifers in the same herd with the older cows. Dominance is principally related to body weight, but is also positively correlated to lactation number; however, production can increase when dominant and subordinate cows, which are offered forage in a competitive situation, are separated (Phillips and Rind, 2002). If primiparous cannot be separated, it is essential to mix pregnant heifers and dry cows for 2-3 months before calving. Grouping strategies for primiparous and multiparous cows become more important in automatic milking systems. Bach et al. (2006) reported how primiparous cows grouped together had numerically more visits to the robotic milking unit (3.26 vs 2.68±0.15) and to the feed troughs (4.91 vs 4.02±0.43), but apparently spent less time eating (2.72 vs 3.22±0.1 h/d) than primiparous cows grouped with multiparous cows.

Stocking density, with reference to total available area per head and particularly to the straw-yard area, is of course of major interest for cow welfare. Overstocking can affect the lying and standing behaviour of the dairy cattle because competition for stalls is increased causing a reduction of lying time and a higher standing time outside the stalls (Fregonesi et al., 2007). Contemporary, leg stomping, repositioning, and weight shifting behaviours all increased in frequency when cows were deprived of an appropriate area for lying (Cooper et al., 2007).

Human-animal interaction

Milking in indoor loose systems typically involves cows being driven to and crowded at the collecting area, to be individually mi-
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... looked in a milking parlour twice a day. If not properly managed, these stockman activities can produce fear, anxiety and pain. Afterwards, the possible fear of the milker and discomfort caused by the technical milking procedure may cause the cows to be unpleasantly affected by milking, and this constitutes a great welfare problem in dairy cattle herds (Rousing et al., 2004). The effects of human interaction, besides some direct cow manipulations and the usual daily labour in the barn, have been demonstrated (Bertoni et al., 2005). Milk production by dairy cows is affected by the behaviour of the stockman towards the animals (Seabrook, in Broom and Fraser, 2007).

However, even if plasma cortisol concentration may slightly increase, welfare is not compromised if proper handling is done (Bertoni et al., 2005). On the contrary, the cow fear of humans has been shown to result in production losses of 10% (Tyson, 2004). In a recent study (Tyson, 2004) the human approach to cows was split into two groups, pleasant and aversive; a pleasant interaction involves patting, stroking and touching, particularly the head area and around the ears. Aversive interaction involves slapping the animals around the heads and nose, and light hitting with a stick or hose. Milk yield increased 14.7% with pleasant over aversive handling (Tyson, 2004). Handling also affected the way animals behaved in the parlour: easier milking operations and less manuring (Tyson, 2004).

Factors that might influence the human-animal relationship are genetic predisposition and housing conditions, as well as experience with quality and quantity of human contact. Human-animal interactions are often limited to a few handling situations, i.e. moving individual animals to calving boxes, restraining cows for veterinary treatment or insemination, driving cows to the collecting area for daily milking etc. Therefore, it seems reasonable to suppose that some training practices to accustom the animal to a new environment might result in a positive outcome. One example may be considered that of Wicks et al. (2004), where dairy heifers in late gestation were trained to pass through the milking parlour and to be touched for udder pre-milking preparation.

Fear of humans might be associated with unpleasant experiences related to forceful handling, and this may explain why the cows demonstrate aversion or attempt to escape during milking. If the cows are in pain or are experiencing discomfort, this may in itself, or in combination with possible fear of humans, cause cows to be unpleasantly affected by milking. Rousing et al. (2004) found that stepping and kicking behaviour during milking were related to reaction towards humans as well as to health status. A complex relation was found between stepping during milking and avoidance behaviour at the clinical examination, behavioural response in the human approach test, teat lesions, actual daily milk yield as well as parity, indicating that stepping during milking may occur in response to general discomfort and it is more expressed in young and/or high yielding cows or in cows responding fearfully towards humans.

Welfare and health

It is obvious that a good health is a “sine qua non” condition of welfare (third freedom... from pain, injury and disease). Everybody knows, in fact, that a low level of health is a cause of physical pain and psychological depression (see the effects of pro-inflammatory cytokines, by Johnson and Finck, 2001). Furthermore, health impairment is a consequence of chronic stress (Elsasser et al., 2000) and a vicious cycle can occur: a low level of welfare, immune depression, disease, low level of welfare... (Broom, 2006). The-
Therefore, any type of pathology involves some degree of poor welfare (Broom, 2006), while pathological conditions can be caused by genetics; physical, thermal and chemical injuries; infections and infestations; metabolic abnormalities and nutritional disorders (as shown in the previous chapters).

This very close relationship between welfare and disease could contribute to better understanding why welfare is also so important for greater animal efficiency (of major interest for the farmers). In fact, disease stress is due to a release, by the immune system cells, of pro-inflammatory cytokines. They are normally strictly controlled and in very low concentrations (particularly, Tumor Necrosis Factor-α, TNF-α), but they can start a series of responses which are potentially deleterious to animal health (Elsasser et al., 2000). These cytokines are released when infectious diseases occur, but also when trauma, injuries, gastro-intestinal endotoxins, oxidative stress etc. cause tissue damage and then an inflammatory response (Grimble, 1990). Therefore, they can be in relationship with many unsuitable husbandry conditions. Among the other effects, cytokines increase body temperature, induce anorexia, increase catabolism (mainly from adipose and muscle tissues), determining several endocrine and metabolic changes (Elsasser et al., 1995). Some of

Figure 4. Pathogens activate immune cells, causing them to produce inflammatory cytokines. The cytokines mediate the immune response but also act on other systems and affect metabolism (adapted from Johnson and Finck, 2001). Photos by the Authors.
these effects can be particularly pernicious in the peripartum period: anorexia, catabolic conditions and fever, adipose mobilization, but in particular, significant changes in liver activity (Bertoni and Trevisi, 2006). All together, these effects can increase the occurrence of many metabolic diseases (namely ketosis and liver lipidosis), but also infections and therefore cause a reduction in welfare status (Figure 4, adapted from Johnson and Finck, 2001).

Besides the reduction of DMI in periparturient cows, confirmed by us in the last part of the dry period (Trevisi et al., 2002), the negative effects of pro-inflammatory cytokines on energy balance are associated with the catabolic conditions, and particularly by the increase in body T° (fever). Furthermore, according to Klasing (2000), the pro-inflammatory cytokines cause an increase in resting energy expenditure, an increase in futile cycles (biochemical definition of “useless” consumption of ATP aimed to a better regulation of some functions) and, consequently a decrease in feed conversion efficiency. In the case of early lactating cows, this means a worsening of the energy balance and greater risks for health and fertility (Bertoni et al., 2008). Our results (Trevisi et al., 2007) have confirmed that cows affected by inflammatory conditions after calving - still without marked clinical symptoms - show lower energy efficiency (10-15%) and can fall victim to metabolic-infectious diseases, thereby worsening their level of welfare.

Conclusions

Dairy cows are generally bred in intensive farms that can permit an acceptable or good level of welfare conditions if well managed. These are namely the following:
- careful attention to the genetic background of the animals can be useful in keeping animals that are suitable for the given farming conditions;
- buildings and equipment must be in accordance with the animal requirements;
- their maintenance and management must guarantee optimal life conditions;
- feed quality, diet composition and feeding methods must cover nutritional needs and guarantee good digestive function in the different stages of production life;
- social interaction between animals and with humans must be gentle and/or enjoyable;
- good health conditions must be ensured as much as possible because any type of clinical or sub-clinical disease can cause suffering and a low level of welfare.

The welfare evaluation of dairy cows has not been discussed because there is a specific companion paper on that topic (Calamari and Bertoni, 2009).

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