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Impact of housing system on intensive beef cattle welfare and production

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RIASSUNTO

Nel corso degli ultimi 30 anni sia l'opinione pubblica che la comunità scientifica hanno dimostrato un crescente interesse verso il benessere animale, che si è tradotto in un aumento delle pubblicazioni scientifiche su questo tema, nonché nella emanazione di svariate leggi e linee guida da parte dei legislatori, ed una maggiore attenzione da parte del consumatore nella scelta dei propri alimenti. Le leggi emanate dall'UE hanno mirato alla massimizzazione della produzione degli allevamenti, assicurando al contempo appropriati standard di benessere agli animali; questo progresso permetterà di ottenere un miglioramento nella qualità dei prodotti finali (es. carne). All'interno della comunità europea l'allevamento del vitello da carne è meno estensivo rispetto all'allevamento di suini ed avicoli, tuttavia molte fasi nel processo produttivo potrebbero potenzialmente incidere sul benessere animale, come per esempio le condizioni climatiche estreme, la castrazione, la decornazione, il trasporto, la manipolazione e l'abbattimento. Inoltre alti livelli di stress possono ridurre l'efficacia della risposta del sistema immunitario, favorendo l'insorgenza di patologie. Queste malattie possono poi causare perdite economiche, legate alle spese veterinarie, scarse performances di crescita, abbattimenti e riforma anticipata. La fase di ingrasso, specialmente nelle aziende di tipo intensivo ed industriale, predispone ulteriormente gli animali ad altre potenziali fonti di stress, quali uno scarsa disponibilità di spazio/capo, un ristretto fronte mangiatoia, pavimentazioni innaturali e non confortevoli, microclima e relazioni uomo-animale non ottimali. Sulla base di questo background lo scopo generale di questa tesi è stato quello di approfondire il tema del sistema di ingrasso del vitellone da carne, per comprendere quali siano i metodi di allevamento che maggiormente incidono sul benessere di questi animali, provando ad identificare i sistemi di allevamento in grado di garantire un maggior benessere agli animali e una migliore sostenibilità economica agli allevatori.

L'obiettivo dei primi 3 contributi di questa tesi è stato il valutare come la pavimentazione e la fase del ciclo di ingrasso potessero influire sulle performances di crescita, livello di pulizia, comportamento e parametri clinici in vitelloni ingrassati intensivamente. Il primo ed il secondo lavoro sono stati basati sulla comparazione tra lettiera permanente e pavimentazione in grigliato; questi due tipi di pavimentazione sono i più frequentemente utilizzati nell'allevamento del vitellone da carne a livello europeo. Il terzo contributo ha avuto come scopo quello di approfondire le conoscenze sull'utilizzo di potenziali soluzioni alternative al grigliato semplice a stecche, valutando gli effetti di tre tipi di pavimentazione discontinua: grigliato a stecche, grigliato a fori e grigliato a fori coperto da un tappetino in gomma. Lo stato sanitario degli animali è stato valutato attraverso la registrazione della presenza di alcuni indicatori, quali lesioni tegumentali, scolo nasale e oculare, tosse, zoppia e bursiti e altri segni clinici di patologie. E' stata inoltre effettuata una dettagliata osservazione comportamentale, annotando la posizione di ruminazione, l'atteggiamento di decubito, il comportamento sociale e la distanza di fuga alla mangiatoia. Sono poi state considerate alcuni indici produttivi, quali l'ingestione alimentare, l'incremento giornaliero medio, il tasso di riforma e la mortalità. Ad ogni animale è stato inoltre attribuito un punteggio che esprimesse il grado di pulizia del mantello.

I risultati hanno dimostrato come il grigliato influenzi negativamente sia i parametri clinici che comportamentali. I bovini allevati su grigliato sono risultati maggiormente soggetti a riforma anticipata a causa di affezioni locomotorie, mentre per la lettiera permanente la riforma sembra per lo più legata a patologie respiratorie. Il confronto tra tipi di pavimentazioni discontinue ha mostrano come le performances di accrescimento dei vitelloni stabulati su tappetino siano più elevate rispetto a quelle degli animali allevati su grigliato semplice, sia esso a stecche o forato. Il contatto diretto con una superficie dura e discontinua ha causato un aumento di incidenza di bursiti, di lesioni cutanee zoppie. Gli animali allevati su lettiera hanno mostrato una minor frequenza di lesioni tegumentali, ma dal lato opposto il loro grado di pulizia è risultato inadeguato, probabilmente a causa di una cattiva gestione della lettiera. Gli animali stabulati su tappetino hanno evidenziato un sovraccrescimento anomalo degli unghioni, legato all'insufficiente consumo e usura dello zoccolo contro la superficie troppo liscia della gomma; nel caso ipotetico di un allungamento del ciclo di ingrasso questa alterazione potrebbe predisporre all'insorgenza di zoppie. Gli animali stabulati su grigliato hanno mostrato una alterazione comportamentale, specialmente a carico di quei comportamenti che richiedano un buon equilibrio ed una adeguata tenuta del piede sul pavimento, come monte e transizioni dal decubito alla stazione e vice versa. La copertura in gomma ha notevolmente ridotto la frequenza di alcuni comportamenti anomali, come scivolamenti, coricamenti infruttuosi o anormali, permettendo agli animali di manifestare in maniera più naturale i comportamenti del proprio etogramma.

Per quanto riguarda gli effetti esercitati dalla fase di ingrasso sugli indicatori di benessere presi in esame, gli animali più giovani e leggeri sono risultati essere maggiormente suscettibili alle patologie respiratorie e aree alopeciche, verosimilmente perchè maggiormente stressati dall'adattamento al nuovo ambiente di allevamento; tali animali hanno inoltre dimostrato una maggiore distanza di fuga all'avvicinamento da parte di un essere umano. Gli animali valutati alla fine del ciclo di ingrasso, quindi più pesanti, sono risultati essere più attivi e maggiormente soggetti a lesioni cutanee e ad un grado di pulizia minore.

I risultati di questi primi tre contributi hanno dimostrato come l'utilizzo di materassini in gomma comportino un significativo miglioramento del benessere dei vitelloni allevati intensivamente, sebbene il consumo dello zoccolo garantito da questo rivestimento non sia risultato sufficiente. La lettiera permanente resta la scelta più rispettosa del benessere degli animali su di essa stabulati, ma solo a condizione che sia efficacemente gestita, il che comporta l'utilizzo di una quantità adeguata di materiale da lettiera ed un suo frequente rinnovo.

L'ultimo contributo si discosta nettamente dai precedenti: in questo caso il modello di allevamento è stato il sistema intensivo nord-americano, basato sull'ingrasso di manzi all'aperto, in grandi box privi di pavimentazione e tetto (feedlots). L'obiettivo di tale lavoro è stato quello di ottenere un quadro generale sull'entità del problema "zoppia" a livello di box infermeria, confrontando poi i risultati con quelli di altri problemi sanitari che comunemente affliggono i bovini in questa realtà produttiva. Un ulteriore obiettivo è stato quello di valutare come la zoppia incida sulla produttività di questi bovini da carne. L'importanza della zoppia nel sistema nord-americano è stata confermata dai risultati della nostra ricerca, dove la prevalenza media della zoppia nell'ambito dei box infermeria è stata stimata pari al 37%, interessando più frequentemente gli arti posteriori. Gli animali zoppi tendono a trascorrere un maggior tempo coricati o fermi in stazione, a cui consegue una diminuzione dell'ingestione di alimenti e dell'assunzione di acqua; le performances di crescita risultano quindi diminuite. Quando confrontati con gli animali ricoverati in box infermeria per problemi di salute di altra natura, gli animali affetti da zoppia hanno fatto infatti registrare un calo significativo dei propri incrementi ponderali. Uno stato di lieve disidratazione può inoltre giustificare il riscontro di valori di RBC; HTC e HGB ematici più elevati negli animali zoppi. I bovini trattati per zoppia hanno però evidenziato valori più bassi di alcune componenti ematiche appartenenti alla serie bianca (WBCM MONO e GRAN), risultati elevati nei soggetti trattati per patologie respiratorie, normalmente più generalizzate. Gli animali trattati per patologie respiratorie semplici o associate a zoppie hanno ricevuto un maggior numero di trattamenti rispetto agli animali affetti da altre categorie di patologie. Gli animali affetti da malattie respiratorie e zoppia concomitanti sono stati generalmente trattati ad un numero di giorni dopo il loro arrivo inferiore rispetto alle altre categorie, mentre per le altre patologie il momento dell'insorgenza è risultato essere più tardivo (fase media e finale del ciclo di ingrasso). Gli animali affetti da patologie respiratorie o da zoppie in forma semplice sono stati generalmente trattati la prima volta nella fase intermedia del loro ciclo di ingrasso.

Questo ultimo studio ha permesso di ottenere un quadro generale del problema delle zoppie nei feedlots nord-americani, problema che è probabilmente sottostimato da parte degli allevatori e delle industrie, mentre l'opinione pubblica ne è fortemente sensibilizzata. L'interesse degli allevatori andrebbe comunque convogliato verso la riduzione dell'incidenza di zoppie in allevamento, mosso dalle ingenti perdite economiche legate alle ridotte performance produttive, al maggiore riforma e ai costi addizionali per le cure mediche. L'introduzione di un piano d'azione per ridurre le zoppie ed altri fattori di rischio per il benessere dei bovini da carne potrebbe essere inoltre un modo per promuovere futuri accordi commerciali, che potrebbero consentire all'industria canadese l'esportazione delle proprie carni verso partner internazionali come l'Unione Europea, da tempo indirizzata verso sistemi produttivi che sostengano il benessere animale.

SUMMARY

Over the past 30 years the interest on animal welfare is increased significantly among both public opinion and scientific community. This growing interest entailed to numerous scientific publications concerning this topic, a greater consumer's attention in food choice and many community laws and guidelines enactment. The EU, with these laws, aims to maximize livestock production, ensuring at the same time appropriate welfare standards to animals; this progress will allow to obtain an improvement in final product quality (e.g. meat). Within the European Community, the beef cattle farming is less intensive than pig and fowl rearing system, but many phases during this process could potentially affect animal welfare, such as extreme climate, castration, dehorning, transport, handling and slaughter. In addition high stress levels are able to reduce immune system response efficiency, then promoting diseases onset. Diseases could obviously entail economic losses due to veterinary costs, poor growth performance, culling and early deaths. Many other potential sources of stress could affect animals during the fattening period, especially within the intensive and industrial farms: space allowance, space at the manger, flooring, micro-climate and human-animal relationship represent some of these welfare risk factors.

Based on this background, the general aim of this thesis was to delve into beef cattle fattening system argument, understanding how different intensive housing methods could affect animal welfare, trying to identify the best rearing solution, that would be able to guarantee both animal welfare and farmer's economic advantage and sustainability.

The aim of the first 3 studies of this thesis was to evaluate how pen floor and phase of the fattening cycle may affect growth performance, cleanliness, behaviour and clinical parameters of young bulls fattened under intensive rearing conditions. The first and second works were based on Deep Litter and Fully Slatted floor comparison; this two pen

floors are the most frequently used in beef cattle finishing. The third study aimed at improving the knowledge on potential alternative solutions to the concrete fully slatted floor, evaluating instead the effects of three different types of discontinuous pen floor: Fully-slatted, Fully-perforated and Fully-perforated floor covered by rubber mattress. The occurrence of integumental lesions, nasal and ocular discharge, coughing, lameness and bursitis and other clinical signs of pathologies was recorded as measure of animal health status. A detailed behavioural observation was performed in order to investigate cattle rumination, resting and social behaviour and young bulls avoidance distance at the feeding rack. As performance measurements were considered feed intake, average daily gain, culling and mortality. Lastly a cleanliness score was assigned to each assessed animal.

The results highlighted how the slats affect negatively both pathological and behavioural parameters. Cattle reared on slatted floor resulted more likely to be culled during the finishing because of locomotory syndromes, while on deep litter the risk of culling is lower and it is mainly due to respiratory diseases. Cattle growth performance result to be affected by the type of floor when rubber coated floor is compared with other discontinuous flooring: bulls kept on rubber significantly increased their growth performance, despite being more active. The direct contact with an hard and discontinuous surface increased the incidence of bursitis, hair and skin lesions and lameness. Bulls kept on straw were exposed to a lower risk of skin alterations, but their cleanliness was more likely to be impaired, because of an inadequate litter management. Beef cattle housed on rubberized floor are more inclined to suffer because of overgrown claws, due to an insufficient wearing of the hoof and this might increase the risk of lameness when they're kept on this type of floor for a long fattening period. As regards to cattle behaviour, young bulls raised on slats were reluctant to perform mounting and other behaviours that required a good balance and an adequate foot grip on the floor.

Lying down sequences duration were prolonged too. The rubber covering greatly reduced some abnormalities such as slipping and unsuccessful attempts to lying down, allowing bulls to perform their social ethogram and make transitions in a more confident way.

Regarding the fattening phase, younger animals were more likely to suffer of respiratory disease and hairless patches, probably caused by the stress of adaptation to the new rearing environment and they appeared less confident to be approached by humans. At the end of the fattening cycle, bulls were more active and aggressive, and skin lesions and reduced cleanliness were more frequently observed.

Results of the present study have shown that among alternatives to the fully slatted floor the covering of a concrete discontinuous pen floor with a rubber mattress allowed a significant improvement of the welfare of finishing beef cattle, even if the hoof wearing on this surface is not optimal. When using the deep litter, a proper management of the litter is required and it should imply the provision of an adequate amount of bedding material along with its frequent renewal.

The last study was a different approach to rearing system effect on beef cattle welfare. In this case the rearing model was the North American feedlot system, in which cattle are intensively fattened in no shelter and no floor pens. The objective of this work was to gather descriptive information about the occurrence of lameness in chronic pens by comparing it with the other health problem that commonly affect feedlot beef cattle. A further goal was to better figure out how lameness influences beef cattle productivity. The importance of lameness in feedlot was confirmed by our research findings, where the average lameness prevalence in hospital pens was estimated as 37% and the rear limbs were the more frequently affected. Lame animals were more likely to spend time lying or standing still, reducing their feed and water intake and indirectly their growth performances: lame animals had a significant drop in the inter observation weight gain as compared with cattle recovered in the sick pen for other health problems. The higher

RBC, HTC and HGB values recorded in the blood of lame cattle were a consequence of a slight dehydration. Lameness treated cattle resulted to have lower values for white cell components (WBC, MONO and GRAN) than animals treated for respiratory diseases likely because these pathologies more frequently turn into a generalized disease that stimulate an immune response. Animal treated because respiratory disease and lameness and respiratory disease associated received more treatments in comparison with cattle affected by the other categories of disease. Animals affected by both respiratory disease and lameness were generally treated earlier than the other classes, while the occurrence of other pathologies was more frequent in a middle-late stage of the fattening cycle. Animals affected by single respiratory disease or lameness were generally treated during the middle stage.

This last study provides a general snapshot about lameness issue in Southern Alberta commercial feedlots system, which is probably underestimated by beef farmers and livestock industry, while public opinion is paying much more attention to this problem. However farmers' interest towards lameness reduction should be driven by the economic losses due to impaired growth performances, increased early culling and additional costs for medical treatment. The introduction of an action plan to reduce lameness as well as other risk factors for beef cattle welfare might be a way to promote the Canadian beef industry in future trade agreements with international partners such the European Union particularly addressed towards welfare friendly production system.

1.INTRODUCTION

1. ANIMAL WELFARE

The term "animal welfare" was used the first time to express ethical concerns about animals' quality of life, especially of those reared for food production. Is not easy to give it a precise and scientific definition, but we can assume that animal welfare description should include the concept of full health and adaptation to human-induced artificial environment without suffering (Duncan, 2005). Hughes (1976) defined animal welfare as "a state of complete mental and physical health, where the animal is in harmony with its environment", while Broom (1986) defined the welfare of an individual "its state as regards its attempts to cope with its environment". Lastly Broom and Johnson in 1993 described Animal Welfare as a characteristic of an individual at a certain time that can be assessed and can vary on a range from very good to poor. This assessment should be carried out in an objective way, taking no account of any ethical questions about the systems, practices or conditions for individuals which are being compared. Once the scientific evidence about welfare has been obtained, ethical decisions can be taken. We need to identify and quantify indicators of good welfare as well as those of poor welfare. The best scientific method to assess animal welfare is to measure the response of animals on the basis of certain functional indicators, which have been grouped by Smidt (1983) into 4 criteria groups: behavioural, physiological, pathological and performance.

The most plausible birth date of Animal Welfare related issues is "Animal Machines" book publication in 1964; in his book Harrison puts emphasis on animals suffering, criticizing livestock industry. In 1965 UK government commissioned to the zoologist Roger Brambell and his technical committee, to delve into welfare status of animals intensively reared. In its final report, the Brambell Committee declares that "Welfare is a wide term that embraces both the physical and mental well-being of the animal. Any attempt to evaluate welfare, therefore, must take into account the scientific evidence available concerning the feelings of animals that can be derived from their structure and function and also from their behaviour" (Brambell, 1965).

The concept that "feelings" are an important component of Animal Welfare is scientifically accredited in 1980 by Dawkins, in her book entitled "Animal suffering".

In 1976 in Strasbourg the Council of Europe signed the European Convention for the Protection of Animals Kept for Farming Purposes; two years later at the headquarters of UNESCO in Paris, The Universal Declaration of Animal Rights was proclaimed.

In 1993 the UK Farm Animal Welfare Council (FAWC), based on the Brambell Committee work, set out the Five Freedoms, a key reference point in efforts to improve the protection of animals:

1. *Freedom from Hunger and Thirst* - by ready access to fresh water and a diet to maintain full health and vigour.
2. *Freedom from Discomfort* - by providing an appropriate environment including shelter and a comfortable resting area.
3. *Freedom from Pain, Injury or Disease* - by prevention or rapid diagnosis and treatment.
4. *Freedom to Express Normal Behaviour* - by providing sufficient space, proper facilities and company of the animal's own kind.
5. *Freedom from Fear and Distress* - by ensuring conditions and treatment which avoid mental suffering.

The paper "Animal welfare and veterinary services" was included in the World Organisation for Animal Health (OIE) scientific and technical review series in 1994, providing an overview on the role of veterinary services in ensuring the welfare within community countries.

New rules on animal welfare were established in 1997 by the Treaty of Amsterdam, which came in a special 'Protocol on the Protection and Welfare of Animals'. The protocol recognises that animals are sentient beings and obliges European institutions to pay full regard to the welfare requirements of animals when formulating and implementing EU legislation.

In 2000 Animal welfare is accepted as an integral part of the Community's "farm to fork" policies and is one of the strategic priorities related to the development of more sustainable farming policies included in the White Paper on Food Safety.

In 2001, the Scientific Committee on Animal Health and Animal Welfare (SCAHAW) published a document where animal welfare topic within beef cattle production is examined. It represents the only reference document on beef cattle rearing system we have at our disposal.

Animal welfare was identified as a priority within the 2001-2005 OIE Strategic Plan; for this purpose in 2002 was founded the permanent Working Group on Animal Welfare, for the purpose of overseeing the creation of OIE standards and guidelines, providing consulting services and supporting research and education (Petrini and Wilson, 2005). The future creation of guidelines will be important for the standardization of animal welfare in international trade.

Within a Eurobarometer survey performed in 2005, EU citizens have expressed a growing appreciation towards high animal welfare standards, highlighting the importance of animal protection to European consumers.

To ensure that animal welfare policies were respected on long term in the strategies of the EU, a Community Action Plan on the Protection and Welfare of Animals was adopted in 2006. This plan describes the measures the Commission adopted between 2006 and 2010 in order to develop and ensure protection and welfare to animals reared the European Union and the rest of the world. In addition this plan aimed to clarify the legislation and to make proposals in those areas where it was insufficient. The Action Plan sets out five main areas of inter-action with a view to achieving the above objectives:

- raising the level of minimum standards;
- promoting research and alternative methods in animal testing;
- the introduction of indicators on the well-being;
- better information to professionals and general public;
- supporting international initiatives for the protection of animals.

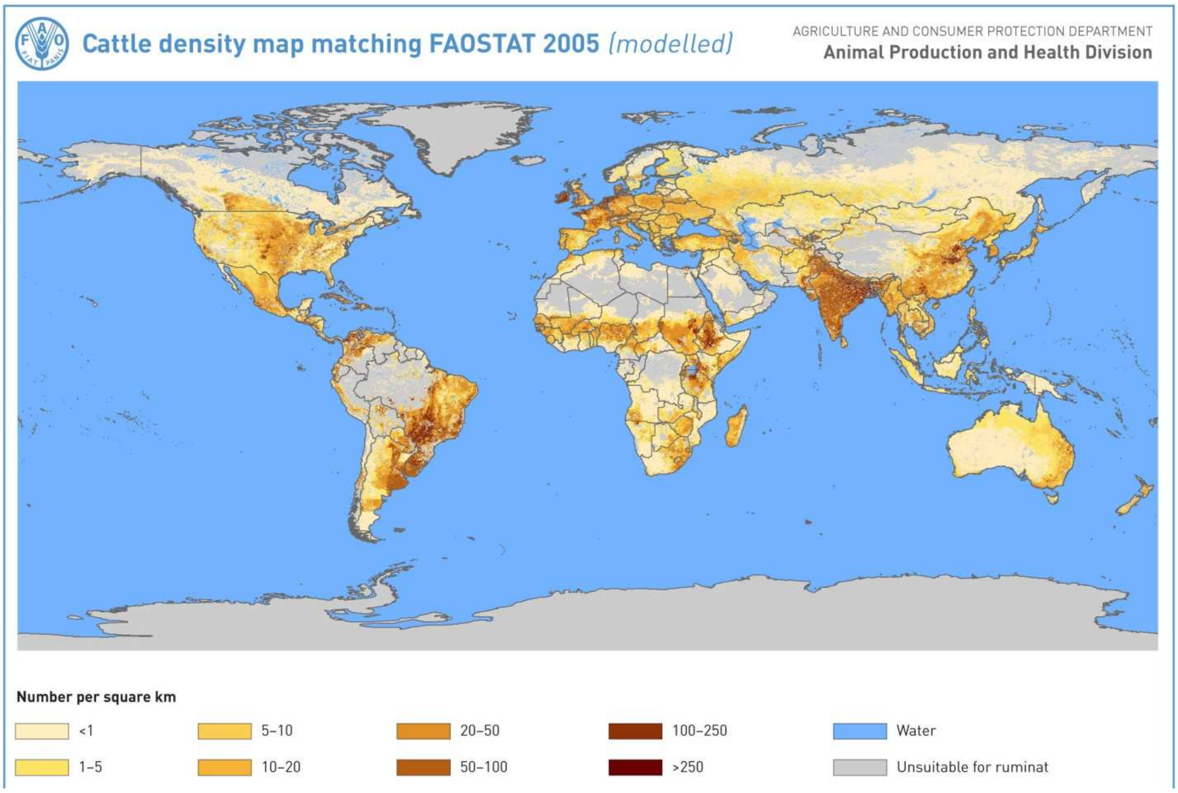
This plan also hopes to promote the recognition of the importance of basal animal welfare standards at the World Trade Organization, allowing access of third country producers to voluntary certification systems. In November 2009, the Commission mandated an external consultant to evaluate the EU policy on Animal Welfare.

The evaluation was completed in December 2010 and will be used as a basis for the future EU action plan: from January 2011 the Commission is preparing the second EU strategy for the protection and welfare of animals (2011-2015) foreseen to be adopted in December 2011.

2. BEEF CATTLE PRODUCTION

The world’s cattle population is approximately one billion, and these cattle are distributed in every continent except Antarctica (Phillips, 2010). Excluding India, where these animals are mostly considered sacred, cattle are usually concentrated into parts of the world in which grass abounds: African savannah, Australia, North American prairies, South American pampas and Central and Eastern Europe steppes. An exception is central Europe where a landless system predominate (Figure 1).

Figure 1 Global cattle density (FAO 2008)



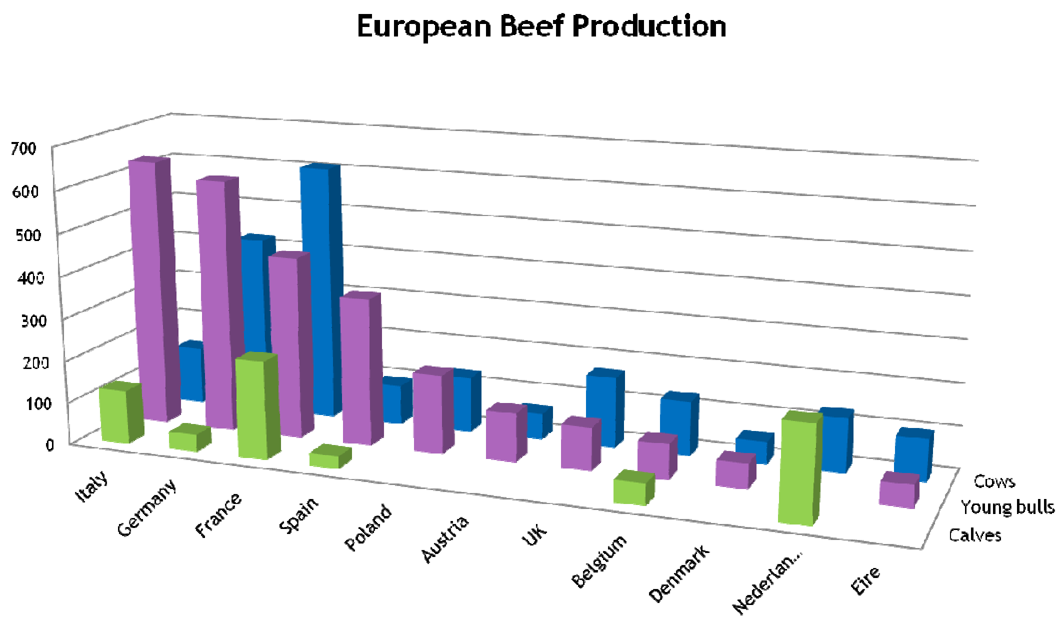
Global beef production tends to be concentrated within the top five producers (the U.S., Brazil, the EU, China and India), accounting for more than 50 percent of global production (Table 1).

Table 1: Global beef production expressed in 1,000 Metric Tons (Carcass Weight Equivalent) (USDA 2010)

Production	2007	2008	2009	2010	2011
USA	12,980	12,163	11,891	11,828	11,556
Brazil	9,303	9,024	8,935	9,145	9,410
EU-27	8,188	8,090	7,900	7,870	7,850
China	6,134	6,132	5,764	5,550	5,450
India	2,413	2,650	2,750	2,850	2,920
Argentina	3,300	3,150	3,375	2,600	2,550
Australia	2,172	2,159	2,129	2,080	2,050
Mexico	1,600	1,667	1,700	1,731	1,775
Pakistan	1,344	1,388	1,457	1,486	1,450
Canada	1,278	1,288	1,255	1,285	1,275
Russia	1,370	1,315	1,290	1,300	1,270
Others	9,359	9,496	8,985	9,038	9,107

Within EU, France results to be the first beef meat producer, providing more than 20% of the European beef meat, divided among these three main classes: cow, veal calf and young bull meat (FranceAgriMer, 2009). Other European countries main production appear to be more specialized: the Netherlands on veal calf, Ireland and the UK on steer, Italy on young bull (Graph1).

Graph 1 European beef production among cattle categories (1,000 Metric Tons Carcass Weight Equivalent) (France AgriMer, 2009).



Italy is the main young bulls producer within the EU, even if most of these animals are originally imported from foreign countries (mainly France, then Poland and Ireland) to be fattened and finished in its own farms (Federici and Rama, 2007).

A large proportion of the offsprings of beef suckler cows in the EU is destined for the beef fattening units. These calves are used to remain with their mother for 6-9 months period before they are weaned. At weaning the calf undergoes a change of diet from milk to a forage diet and changes its environment. The final fattening system, feeding and finishing methods are differentiated by animal genetics, production zones, climate factors and consumers demand for meat characteristics (SCAHAW, 2001). Within EU, male cattle are usually intensively fattened as young bulls and fed with corn silage supplemented with concentrates; the duration of the fattening period could vary from 120 to 250 days, depending on breed and market demand. Anyway dairy breed bulls are frequently slaughtered younger than beef ones. In Ireland, in the UK and in western France males beef cattle are usually castrated and generally reared grazing up 5 months before slaughter; they are then fed with grass silage and concentrates.

In Italy the beef cattle production is concentrate within the Po Valley, the most productive arable cropping area of Europe. Most of the specialised fattening units located in this region has a capacity bigger than 200 heads for unit. Cattle are housed indoors and slaughtered when 18 months old with a mean carcass weight of 350 kg (SCAHAW, 2001). In Italy young bull intensive fattening takes normally place adopting two different housing systems:

• SLATTED FLOOR SYSTEM: Floor in this system is usually made from concrete beams placed parallel to each other, with a small gap or slot between each pair. Optimum slats width is about 150 mm and 40 mm maximum gap between the slats; beneath a tank stores slurry and manure. This system is frequently adopted because it allow to reduce the space allowance required per bull, liquid manure storage, to overcome the unavailability of straw in many areas and decrease operational costs due to reduced labour and no requirement for bedding material. In the other hand it requires a relatively high initial capital cost associated with such structures. A higher docking density is required to ensure sufficient animal treading action to push the waste through the slats, but recommendations have been published for the minimum space allowance for beef cattle in slatted pens (Table 2). This housing solution is strongly criticized by scientific community it doesn’t fully respect cattle welfare. However, in the last years modification to slats surfaces is developing, especially on dairy cattle herds. Slatted floor could be covered fitting soft or rubberised materials on it in order to improve animal welfare, providing more comfort and reducing slipping, frequently reported on concrete floor (SCAHAW, 2001).

Table 2 Recommended minimum space allowance per animal (m^2) excluding troughs on fully slatted floors (SCAHAW, 2001).

Animal liveweight (kg)	Hardy and Meadowcroft (1986)	Dodd (1985)	ADAS
200	1.1		1.1
300	1.5	1.4	1.5
400	1.8		1.8
500	2.1	2.0	2.1
600	2.3	2.2	

• LITTERED LOOSE HOUSE: in this system a continuous concrete floor is bedded with straw or other litter materials. The deep litter system requires approximately 4 to 6 kg of straw per animal per day (Daeleman and Manton, 1987; Tillie et al., 1996) and its lying area is generally cleaned out only once at the end of the fattening period. If an adequate allowance of straw is not provided the animals become dirty as a result of the wet lying conditions, especially if animal density is too high. Bedded pen management obviously require higher labour and material costs. A way to reduce the amount of litter needed is to slope the pen floor (8-10 %) (Compere and Tillié, 1981; Zeeb, 1986). In this way just a small amount of straw (1 to 2 kg/animal/day) has to be distributed daily on the high side of the floor, often next to the trough. The animals gradually thread the straw and manure downwards along the slope and manure has to be removed daily at the lowest point. The surface recommended for littered loose house is around 6 m2 for 600 kg bulls, more than twice of the slatted suggested one (SCAHAW, 2001).

In the Americas and Australia, the main system of finishing cattle is though feedlots, which are confined areas in which cattle are intensively fed over a 2-6 month period till slaughter for meat. Cattle, mostly heifers and steers, are kept in penned groups of about

400, which are usually sloped to allow the liquids to run off into an evaporation pond. Having no shelter as animal protection, the development of muddy conditions in the pen could be common; this condition affects animal welfare and promotes disease transmission. Twice a year the pens are cleared out and the manure spread on neighbouring land. The use of ionophores, coccidiostats and growth promoters here is allowed. The high stocking density, the use of anabolic agents, large group size and mixing of cattle encourages buller steer syndromes, which affect about 2-4% of animals in feedlots, reducing their Welfare (Phillips, 2010).

3. EFFECT OF HOUSING SYSTEM ON BEEF CATTLE WELFARE

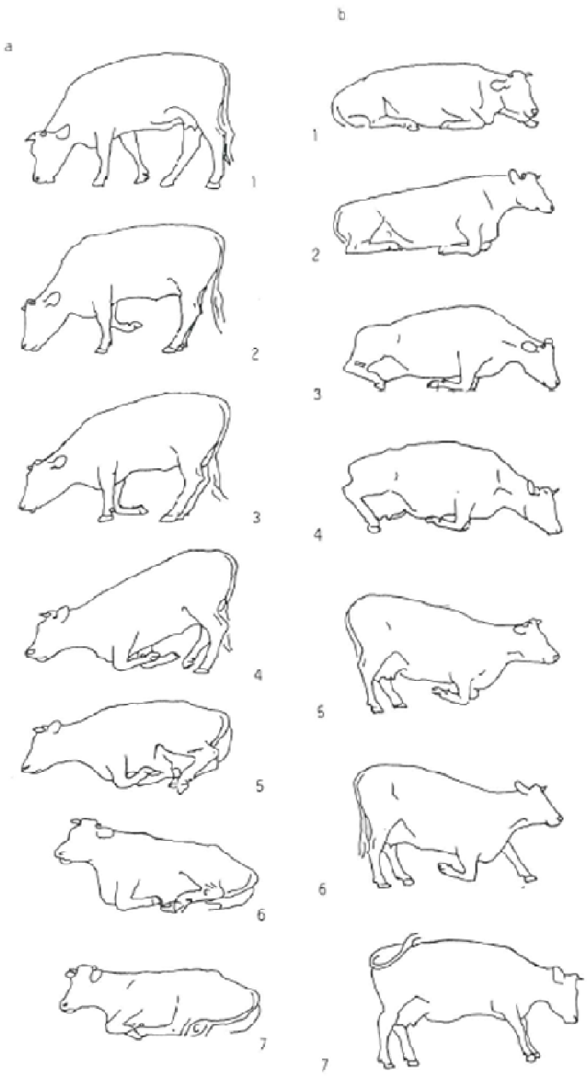
3.1. EFFECTS ON BEHAVIOUR

A behavioural change is the most obvious indicator that animals have difficulties to interact with their environment (Broom, 2000).

Obviously intensive farming conditions are not able to allow animals to fully perform their own ethogram, and these restrictions could affect their welfare. Housing system, as well pen flooring, are able to affect many behavioural traits of fattening animals (Ladewig, 1987; SCAHAW, 2001). Slatted floor is known to become slippery, especially when wet and dirty. When animals walk on this uncomfortable surface, they modify their gait, slowing down and reducing stride length (Telezhenko and Bergsten 2005); however slats rubber coating leds to an increase in step length and number (Telezhenko and Bergsten 2005; Platz et al. 2008). Rubber and litter presence reduces the percentage of slips occurring (SCAHAW, 2001; Gygax et al. 2007; Platz et al. 2008; Absmanner et al. 2009).

Bulls reared on soft flooring show more active behaviours than bulls on concrete slatted floor, while displacement of lying bulls results to be more frequent on rubber coated slats than on fully slatted floor and deep litter (SCAHAW, 2001; Gygax et al. 2007). In addition, on straw the proportion of animal at the same time at the manger appears higher (Gottardo et al, 2003). Mounting behaviour occurrence in cattle housed in deep litter or on rubber flooring resulted anyway higher than slats (Lidfors 1992; SCAHAW, 2001; Platz et al. 2008; Absmanner et al. 2009). Lying is important for cattle and they show a strong motivation to perform it (Metz, 1984). It usually occurs in sternal recumbency, although occasionally cattle can lie down in lateral recumbency. Prolonged lateral recumbency is however normally prevented by the need to eructate gases from the rumen. Compared with cattle housed on slats or rubber coated floors, an higher number of animals housed on straw resulted to adopt this position during resting (Absmanner et al., 2009), even if these findings were not confirmed by subsequent works (Haley, 2000; Rushen, 2007). Steers and bulls kept on straw show a higher number of lying periods and spend more time lying than ones housed on slatted floors (SCAHAW, 2001). In the other hand, animals on slats result to rest without changing body position for longer periods (Ladewig, 1987).

Cattle have an innate movement pattern when lying down and



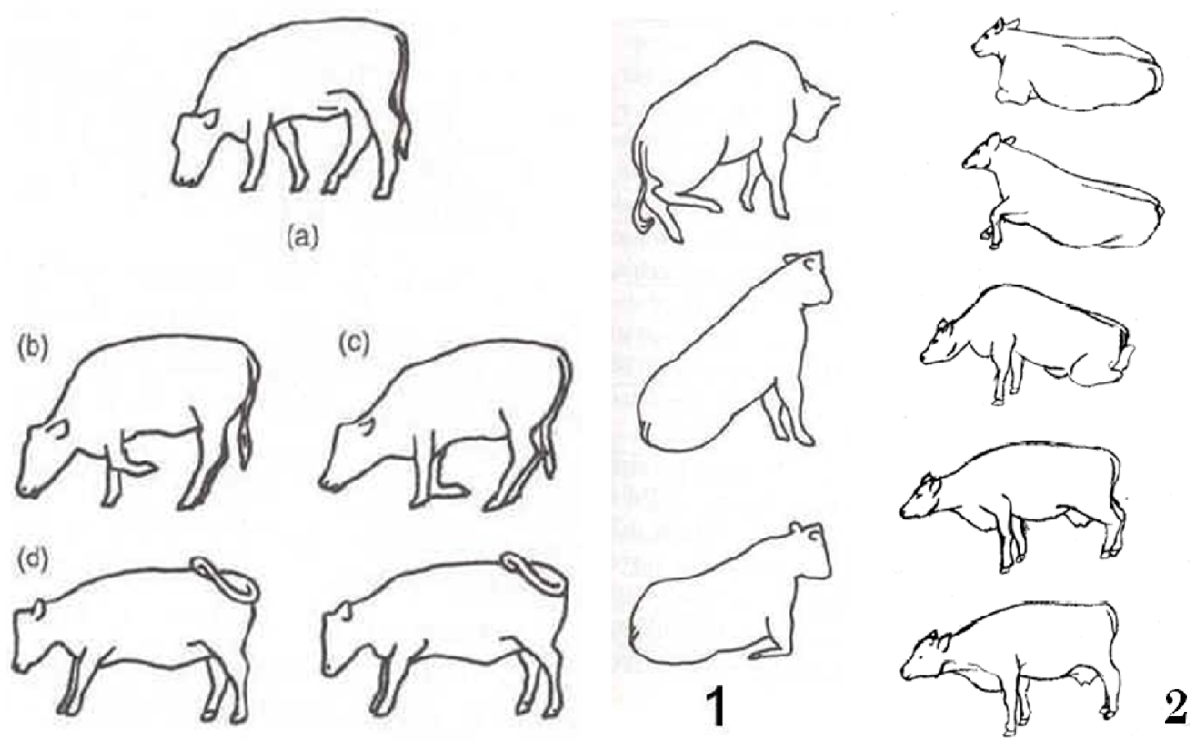
1 **2**

getting up (2) normal
1982)

getting up (Figure 2). When lying down cattle make perpendicular movements with the head over the surface, searching for a suitable place to lie down on. Then they bend one foreleg and place the knee on the surface; at the same time they bend the other leg and place this second knee close to the first one. They may stop shortly, right before descending the hind part of the body slowly downwards, and lastly the front legs are moved forward a bit so that the animal is lying in a comfortable position. When getting up cattle move to an upright lying position, and place the front legs under the breast region. Then they make a swinging movement forward which helps in raising the hind part of the body. From the kneeling position, cattle first stretch one front leg and then the other. They may also get up through a sitting position like a horse or dog; this is however quite unlikely to occur in younger fattening cattle if they are healthy (SCAHAW, 2001). Animals may have problems in performing the normal lying down pattern on inadequate, hard and slippery surface, as such as slatted floor (SCHAW, 2001). The incidence of abnormal transitions (Figure 3; 1-2) is higher in cattle kept on slatted floors than on straw or on rubber-covered slats, as confirmed by several works (Lidfors, 1992; Fraser and Broom, 1996; SCAHAW, 2001; Gygax et al., 2007; Absmanner et al., 2009).

A lower frequency of lying down and getting up transitions and a reduced number of lying bouts has been reported on slats in comparison with straw (Sambraus, 1980; Andreae and Smidt, 1982; Lidfors, 1989 and 1992; Gygax et al., 2007; Absmanner et al., 2009), while Haley et al. reported the same trend on slats when compared with rubber mattress floor (2001). At the same time, lying bouts duration on straw and rubber appeared to be shorter if compared with slats and concrete (Haley et al, 2001; Hickey et al 2002 and 2003; Gygax et al., 2007; Absmanner et al., 2009). The duration of both lying down and getting up transitions appears to be affected by housing system, resulting both shorter on straw than rubber coated slats, than simple slats (Platz et al., 2007; Absmanner et al., 2009). Cattle on slatted floor are more likely to show interrupted lying down sequences (Andreae and Smidt 1982; Lidfors 1992; Gygax et al 2007), spending also more time investigating the lying area (Ladewig, 1987; Lidfors, 1989) (Figure 3 a-d).

Figure 3 Interrupted lying down sequences (a-d) and abnormal lying down (1) and getting up (2) sequences (Andreae e Smidt, 1982)



For cattle rumination is essential: within grazing conditions, this activity takes mostly place when animals are lying; obviously if they're unable to lie down and relax, rumination efficiency could be affected and reduced (Phillips, 2002). As well as resting, self-grooming is another physiological behaviour cattle are used to spend a significant amount of time performing it. This activity allows animals to keep their coat clean and free from ectoparasites, but in a stressful situation its performance result reduced. For that reason cleanliness could be used as poor welfare indicator (Phillips, 2002; Platz et al 2008). Many works investigated cattle cleanliness, comparing housing systems, but obtaining different results: O'Hagan Steen (2000), Lowe et al. (2001) and Schulze-Westerath et al. (2007) reported cattle reared on straw to be cleaner than on slats. The opposite findings are described by Hickey et al. (2002) and Gottardo et al. (2003).

3.2. EFFECTS ON HEALTH STATUS

Good health is necessary for good welfare. Many diseases could be associated with intensive rearing systems and inadequate welfare status. Lameness is one of the most common disease affecting dairy cows; in approximately 90% of lameness cases, the hind limb is the involved one. Lame cows tries to reduce the pain by minimizing the propulsion of affected limb, reducing gait speed, arching its back and lowering both neck and head (Phillips, 2002).

Lameness is one of most important diseases of beef cattle intensively housed (Hanan and Murphy, 1983; Murphy et al., 1987). Lesions vary from tendon and muscle injuries (Sturén, 1985), to hoof and foot diseases (Jensen et al., 1981; Murphy et al., 1987; Davies, 1996).

Slatted floor appears not to be the able to guarantee a low lameness incidence: both joint and claw lesions result to be more frequent on slatted floor than on rubber coated slats or deep litter (Murphy et al., 1987; Wierenga, 1987; Dumelow, 1993; Smits et al., 1995; Vokey, 2001; Somers et al., 2003; Bergsten, 2003; Sogstad et al., 2005; Shulze Westerath et al., 2007). In the other hand bulls reared on deep litter or rubber coated slats have fewer hoofs wear and require more frequent hoof trimming (Andersen et al., 1991; Platz et al., 2007; Telezhenco et al., 2009). Further, lameness occurrence appears higher for cattle housed on sloped littered floor, and lower on deep straw bedding (ITEB, 1983) (Table 3).

Table 3 Influence of the housing system on the number of fattening beef bulls treated for leg problems (ITEB, 1983)

Type of housing	Number of animals	Lameness occurrences during the fattening period (%)
Cubicle house	160	23
Sloped floor	120	36
Slatted floor	510	26
Straw bedding	230	14

Tail tip necrosis is a multifactorial disease and is particularly related to the quality of the pen floor, to high stocking density and high environmental temperature (Madsen, 1987; SCAHAW, 2001). It's due in most cases to traumatic injuries (tail tramping) which subsequently become infected. The lesion usually begins at the tip of the tail with a typical inflammatory reaction that gradually extends upwards. Economic losses are due to reduced weight gain, death and veterinary costs. This pathology is more frequently reported in young bulls housed on slatted floors (Madsen, 1987; Ingvartsen and Andersen, 1993; Schrader et al., 2001; SCAHAW, 2001)

3.3. EFFECT ON PERFORMANCES

When welfare status is not optimal, animals show lower productivity and performances; this phenomenon is well known in dairy cattle, where the milk yield could suddenly fall (Napolitano et al., 2005); the same happen in beef production, even if not equally evident. In addition poor welfare and stress can induce immunosuppression, favoring diseases outbreaks and affecting culling and mortality rates (Gregory, 1998).

In comparison with slats, fattening bulls reared on rubber coated floor or littered pen show better productive performances (Irps 1987; Mogensen et al., 1997; SCAHAW, 2001; Dunne et al., 2008). Lastly, mortality and culling rates were reported to be higher on bulls housed on slatted floor than on straw bedding (ITEB, 1983; Cerchiaro et al., 2005).

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2.RESEARCH ACTIVITY

I - Differences in behaviour, health status and productive performance of beef young bulls housed on different type of floor and assessed in two fattening phases

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1.INTRODUCTION

In the last years the welfare issue has become one of the main research topics in beef cattle product, particularly after the publication of the EU report on beef cattle welfare (SCAHAW, 2001) and the Community Action Plan on the Protection and Welfare of Animals (EC, 2006). In this context many scientific groups addressed their research activity to find reliable measures that can be used directly on-farm to evaluate the welfare level of beef cattle. When a good welfare level is provided, cattle has to ideally show a good health status and optimal performances and it should be able to perform a natural behaviour. It is common opinion that rearing systems with a high stocking rate are negatively related to the animal well being, since for the large majority of the urbanized people the perception of farm animal welfare is related to a 'natural' behaviour in a 'natural' environment (Webster, 2001). Among farm animals, beef cattle are particularly at risk of poor welfare due their intensive rearing systems adopted in many EU Countries and Italy in particular. In 2008 Italy resulted the main young bull producer within the 27 EU Countries (633,5 million of bulls over 2.967,2 million of the whole EU) and the most important feeders importer (ONIEP, 2007; Cozzi et al., 2009). Beef cattle are imported from other EU countries (France mainly) to be finished in specialized fattening units. Right after the arrival, animals undergo to a set handling procedures, such as prophylaxis and regrouping. Animals are then housed in multiple pens having as floor deep litter or slats (Cozzi, 2007) and they are fed a high concentrate diet until they reach a proper finishing. All these events, as well the change of the rearing environment and the new feeding and housing conditions have shown to be potential stressors for cattle, impairing their welfare status and promoting diseases outbreak (Galyean et al., 1999). Some of these pathologies and health problems (as shipping fever, lameness and mycosis) are more frequent in the first period of the fattening cycle, when cattle are stressed and more likely to contract disease, sometimes severe and lethal (Moberg et al., 2000). These diseases, if not adequately treated, may affect growing performances and increase early culling and mortality, involving economic losses. Older animals are instead more likely to suffer from lameness and joint problems in the last phase of their fattening cycle, when they reach heavy live weights. Deep litter and slatted floor are the two types of pen floor more frequently adopted by the European intensive farms and they could potentially hardly affect beef cattle welfare. Slats in particular are considered not completely respectful of cattle needs and have been severely criticized by some welfare experts (SCAHAW, 2001).

A bull that live in a constant stressful situation, like under intensive housing condition, will probably show sub maximal productive performance impairing parameters such as daily intake, daily gain and feed conversion ratio. Lowe et al. in his work (2001a) reported that unsuitable housing facilities can negatively affect besides performance, also carcass composition and meat quality. In addition mortality and early culling appear more likely to happen when beef cattle are exposed to stressful conditions (SCAHAW, 2001) .These indexes as well as the animal cleanliness score can be used as valid parameters to evaluate farm management efficiency and indirectly as animal welfare indicators (Cozzi et al., 2006). Cattle reared in a natural environment are used to keep their fur clean and free from parasites performing self and allo-grooming. When stressed or raised under a not appropriate hygienic management, the time they spend in such behaviour gets shorter

(Phillips, 2002). The cleanliness level on different housing systems was considered in several studies but the results appear contrasting: Lowe et al. (2001a) found a higher dirtiness value on cattle housed on slats than on deep litter, while Cozzi et al. (2005) and Gottardo et al. (2003) reported the opposite results. Coat severe dirtiness should be avoided both for economic and for welfare reasons (Lowe et al., 2001a). Other factors that may influence animal cleanliness are the litter renewal and management, animal space allowance and diet. Deep litter appears to allow a more suitable resting comfort (Phillips and Schofield, 1994; Tuyettens 2005), while an hard floor surface can affect the resting and standing behaviour of cattle, as well alter the duration and the normal sequence of lying down and getting up transitions (Wierenga 1987; Ruis-Heutinck et al., 2000; Absmanner et al., 2009). Wierenga (1987) in his work described that animals housed on concrete are more careful when lying down and standing up to avoid accidents. This could lead to a less than optimal load on the joints and consequently to injuries. These injuries can also occur when animals slip, or try to avoid slipping, if the floor has insufficient grip. Schulze Westerath et al. (2007) showed that severity and incidence of leg lesions and lameness seems to increase with the animal live weight when they're housed on fully slatted floor, while on deep litter this incidence results lower and its trend appears constant during the whole fattening cycle. A similar result was found by Cozzi et al. 2005 and Platz et al., 2007. Lame bulls result less motivated to walk and eat, and they are likely confined to a lower hierarchy class, then more frequently attacked by pen-mates. Recumbency on concrete slats and slipping during transitions seems to increase the incidence of integumental lesions and wounds, affecting especially the carpal-tarsal area (Schulze Westerath et al., 2007). Claw horn lesions are another major cause of lameness for cows housed on hard concrete floors (Bergsten and Frank, 1996; Faull et al., 1996). Finally tail tip necrosis incidence appears to be higher on slatted floors than on other types of floors (SCAHAW, 2001). Type of floor and fattening phase could affect some behaviours as mounting and chasing that were more seldom performed by cattle housed on slats than on straw, probably because a less sure foot grip on the floor surface (Platz et al. 2007).

The aim of this study was then to compare the two pen floors (Deep Litter, DL, and Fully Slatted, FS) more frequently used in beef cattle finishing taking into account their effect on behaviour, health, cleanliness and productive performance at two different phases of the fattening cycle (Initial and Final).

2. MATERIALS AND METHODS

2.1. ANIMALS, HOUSING AND MANAGEMENT

The study was carried out in a commercial beef farm located in the Eastern Po Valley during the period from October 2008 to January 2009. This farm has a total of 5500 fattening places divided among 29 barns. A large majority of fattening places (3500) is on fully slatted floor while just one third of them are on wheat straw and sawdust deep bedding. The farm adopts an open cycle rearing system, in which newly received bulls are weekly introduced. Animals, Charolais and French crossbreed young bulls, are imported from France at approximately 400 kg of live weight and are housed in multiple pens till slaughter. As soon newly received bulls come in the farm they are all immunized against respiratory diseases (IBR, Syncytial Respiratory Disease, Parainfluenza viruses) and treated using antiparasitics. Bulls are daily checked by the farmer in order to verify their health status and they are feed once a day (in the morning) with a TMR, formulated to allow a satisfactory finishing. Each pen has one or two automatic bowls for the water supply. The research considered a total of 27 batches of bulls housed on deep litter (DL) or fully slatted floor (FS) pens. The proportion between the two types of floor reflected the real farm situation and within each floor type, batches were subdivided according to two phases of the fattening cycle (Initial and Final) (Table 1).

Table 1 Partition of the batches of beef cattle considered in the study according type of pen floor and phase of the fattening cycle (mean ± SD).

	Deep Litter (DL)				Fully Slatted (FS)			
	Batches	Animals			Batches.	Animals		
Fattening phase	n	mean	SD	Total	n	mean	SD	Total
Intial	4	83.67	30.00	251	11	224.81	44.19	2473
Final	3	80.00	84.89	540	9	237.56	63.18	2138

Fifteen batches of young bulls (4 housed on deep litter and 11 on slats) were observed one month after the receiving day of the animals (Initial phase), while 12 batches (3 housed on deep litter, 9 on slats) were observed the week before slaughter day of the animals (Final phase). Pen size and the number of bulls housed per pen were different between the two housing systems. Deep litter pens housed on average 15 bulls with 3.49 ±0.58 m^2/head of space allowance and 36.2±8.4 cm space at the manger. A mixture of 50 kg of straw and 30 kg of sawdust was added twice a week as bedding material and it was completely renewed every 3 week. Slatted floor pens housed on average 9 bulls, with 2.93±0.1 m^2/head of space allowance and 64.4±3.3 cm/head of space at the manger. The pen floor was made by concrete slats 14 cm width, longitudinal gap width 3.2 cm and 90 cm length.

2.2. ASSESSMENT PROTOCOL AND MEASUREMENTS

The assessment protocol was carried out by the same trained assessor right after feed distribution in the morning and it considered the direct observation of the animals housed in 8 pens per batch. The protocol consisted of a clinical visit, an evaluation of animal dirtiness assessment and a behavioural observation. All the considered measures were carried out according to the Welfare Quality® protocol for cattle (Welfare Quality®, 2009). The productive performance of the observed batches of cattle were recorded from farm sheets. The duration of the finishing cycle and the live weight of the young bulls at the end of it were recorded for the 12 batches assessed at end of the fattening. The percentage of dead animals and the cases of euthanasia and emergency slaughter were also recorded, as well the cause of early culling by using three categories: respiratory syndromes, musculoskeletal system pathologies/lameness and other causes. Other causes category included parasites, heart failure, infectious diseases, urolithiasis, and other minor causes.

Body Condition Scoring was used to assess the bulls fattening and finishing level at the end of the fattening cycle and the scoring scale ranged from “1” (very thin) to “5” (optimal finishing level). Individual bulls’ dirtiness was assessed by observing one side of the body including in the scored area as much of the underbelly as it was visible but excluding head, neck and legs below the carpal joint and hock. When an area of manure of at least the size of two hands of the area in question or more was covered with plaques of dirt, the animal was recorded as dirty.

2.2.1. Clinical observations

Clinical scoring included the assessment of the several measures. The presence of hairless patches (with no skin damage) or lesions /swellings (presence of skin damage) was recorded only if the affected area size was of a minimum diameter of 2 cm at the largest extent. From a distance not exceeding 2 m, one side of the assessed animal have to be examined ensuring a random side selection (left or right). To prevent biased results, the side selection has to be done before the examination. In most cases, the side which is seen first when approaching the animal can be chosen. These body regions are scanned from the rear to the front, excluding the bottom side of the belly and the inner side of the front legs, but including the inner side of the opposite hind leg. When a swelling was due to bursitis, its occurrence were recorded. For the following health parameters, only the presence/absence was recorded assessing the whole animal (not just one side): nasal discharge, ocular discharge, dyspnoea, diarrhoea, bloated rumen and clinical lameness. In order to complete the clinical picture the number of coughs were recorded at pen level, during the 10 minutes long continuous behaviour observation.

2.2.2.Behavioural parameters

In order to assess bulls behaviour, 8 pens for each batch were randomly selected across the barn and they were evaluated according to protocol proposed by Welfare Quality® (2009). The first test was performed just after feed distribution, when most of the bulls were at the manger. To measure the human-animal relationship, avoidance distance at the feeding rack test (ADF) was applied to 60 bulls per each batch in order to evaluate the fear that animals feel when approached by a human being (Windschnurer et al., 2009). The assessor moved towards the animals whose head completely past the feeding rack from a distance of 3 meters at a speed of one step per second and a step length of approximately 60 cm. He approached the animal with his arm held overhand at an angle of approximately 45° from the body, until the muzzle was touched or withdrawal occurred. The avoidance distance was expressed with a resolution of 10 cm and it was estimated as the distance between the hand and the muzzle at the moment of withdrawal. The measurement ranged from 300 cm to 10 cm and when the animal could be touched an avoidance distance of zero cm was recorded.

A continuous behaviour observations was then performed in each pen to quantify bulls' social and resting behaviour (Martin and Bateson, 2007). Before the start and at the end of such observations, a segment scan was performed and the number of feeding, lying and standing animals of each observed pen was recorded. The occurrences of some specific behaviours listed below were assessed for 10 minutes net observation time each pens, classifying as agonistic, cohesive and neutral behaviour. The behaviour patterns are described in Table 2. Head butts, displacements, chasing, chasing up and fighting were classified as agonistic behaviours, and can be defined as social behaviour related to social hierarchy and includes aggressive as well as submissive behaviours. Social licking and horning are scored as cohesive behaviours, whose aim is promoting group cohesion and socializing.

Table 2 Description of behaviour patterns recorded in during the Continuous behaviour observation

Behaviours	Description
Agonistic Behaviours	
Head butt	The actor is butting, hitting, thrusting, striking or pushing the receiver with forehead, horns or horn base with a forceful movement; the receiver does not give up its present position
Displacement	As Head butt but as a result the receiver gives up its position
Chasing	The actor makes an animal flee by following fast or running behind it
Fighting	Two contestants vigorously pushing their heads (foreheads, horn bases and/or horns) against each other while planting their feet on the ground in 'sawbuck' position and both exerting force against each other
Chasing-up	The actor uses forceful physical contact against a lying animal which makes the receiver rise.
Cohesive Behaviours	
Social Licking	The actor licks any part of the body (head, neck, torso, legs, and tail) of another group mate except for the anal region or the prepuce
Horning	Head play with physical contact of two animals
Neutral behaviours	
Mounting	A bull lifts itself up on its hind legs and jumps with its forelegs onto a group mate either from behind, the side or front
Lying down behaviours	
Intentions to lie down	A bull lowers the head and sniffs the ground, paws the ground, repeatedly bends the carpal joint or shifts weight or swings the head and no lying down afterwards
Atypical lying down sequence	A bull lie down with hind legs first

Mounting was considered a neutral behaviour. Social behaviours were recorded taking the animal carrying out the action (actor) into account, while interactions between animals in different pens are recorded if the actor animal head is located in the focus pen. To limiting interferences with the observed animals, the observer was placed outside of the animal area on an elevated platform within the feed bunk, that further allowed a better view of the whole assessed pen. Intentions to lie down and atypical lying down sequences occurrences were included within assessment to obtain more complete information about resting comfort. During these behavioural observation and every time a lying down transition occurred, the observer recorded using a stopwatch the time needed to the bull to perform this movement. The sequence starts when one carpal joint of the animal is bent and lowered and it ends when the animal pulled the front leg out from underneath the body after the hind quarter falling down.

A herd scan was finally carried out approximately 2 hours after feeding in order to detect both the number of the animals that are "lying and ruminating" and the number of animals that are "standing and ruminating" in the previously evaluated 8 pens. Every animal had to be observed at least for 3 seconds for signs of ruminating. These measures would be a better indicator of resting comfort and it was hypothesized that with decreasing resting comfort the proportion of bulls standing during rumination would be higher.

2.3. STATISTICAL ANALYSIS

Batch was set as statistical unit for bulls live weight and culling, while pen was considered for behavioural analysis. Each single animal was considered as statistic unit within ADF, clinical and lying down durations measurements. All behaviour traits and coughing were analyzed by General Linear Model procedure PROC GLM (SAS/STAT, 1990) including type of floor and phase of fattening as fixed effects and the batch as random effect nested within type of floor. The same procedure was performed for investigating herd conditions and productive performances too, whereas the live weight (LW) at the beginning of the cycle was added to the model as covariate when the average daily gain (ADG) was taken as dependent variable. The most completed model including all mentioned factors was as follows:

y = F + B(F) + LW + e,

where y is the trait for the i-th individual (i.e., behaviour, herd conditions, productive performances or ADG) and e as residual random variance.

Clinical traits, recorded as dichotomous variables, were analysed by Logistic Regression procedure (SAS/STAT, 1990) including the effect of the thesis in the statistical model. For these variables, the two floor types were compared by Wald Chi Square Test setting a minimum threshold of significance P <0.05.

3. RESULTS

3.1 HOUSING SYSTEM, PRODUCTIVE PERFORMANCES AND DIRTINESS

The newly received young bulls housed on DL results heavier than the FS ones, but this difference didn't affect average daily gain, as well as final live weight and cycle duration (Table 3).

Table 3: Growth performance of young bulls housed in pens with different type of floor during the finishing period

Type of Floor	DL	FS	P	RMSE
Animal per pen, n	15±1.5	9±1.9		
Initial live weight, Kg	437 ± 26	412 ± 9	*	14.18
Final live weight, Kg	727 ± 28	728 ± 28	n.s.	27.92
Average Daily Gain, Kg/head/d	1.39 ± 0.06	1.45 ± 0.04	n.s.	0.04
Cycle duration, d	216 ± 22	218 ± 6	n.s.	20.02

*=P<0.05; **=P<0.01; ***=P<0.001; n.s.= P>0.05

The outcomes of the logistic analysis performed on dirtiness score are reported in Table 4. Bulls housed on FS were more likely to be clean than DL bulls. Considering the phase of fattening, bulls at the end of the finishing period were likely cleaner than newly received animals.

Table 4 Estimation of the odds ratios for the significant (P<0.05) dirtiness score

Clinical traits	Wald test Confidence limits at 95% Type of floor (DL vs FS)			Wald test Confidence limits at 95% Fattening phase (Final vs Initial)		
	Odds Ratios	Minimum	Maximum	Odds Ratios	Minimum	Maximum
Dirtiness	133.69	60.251	296.665	0.094	0.057	0.156

Body condition score resulted fully satisfactory (BCS=5) for all the animals assessed at the end of the finishing. However, during the during the project 77 bulls were culled due to mortality or early slaughtering. The percentage of culled animals was higher for FS than DL due to a greater incidence of emergency slaughters (Table 5).

Table 5 Culling animals during the study period

	Type of floor			
	DL	FS	P	RMSE
Culling (%)	1.14	3.41	*	1.42
Mortality (%)	0.74	0.88	n.s.	0.78
Early slaughtered (%)	0.38	2.53	**	1.08

**=P<0.01; *=P<0.05; n.s.= P>0.05.

Musculoskeletal system pathologies/lameness was the main cause of early culling in FS pens (71%), whereas respiratory syndromes and other causes were just 11% and 18% of culling causes, respectively. In DL pens, 49% of culling was due to respiratory syndromes, 38% to locomotory system failure and the remaining 13% to other causes.

3.2. CLINICAL OBSERVATIONS

The presence of integumental alterations, such as hairless patches and lesions/swellings, resulted affected by both type of pen floor and phase of fattening (Table 6).

Table 6 Estimation of the odds ratios for the significant clinical parameters (P<0.05).

	Wald test confidence limits at 95% Type of floor (DL vs FS)			Wald test confidence limits at 95% Fattening phase (Final vs Initial)		
Clinical traits:	Odds Ratios	Min	Max	Odds Ratios	Min	Max
Bursitis	0.387	0.179	0.838	8.008	3.898	16.452
Nasal discharge	2.258	1.228	4.153	0.016	0.002	0.117
Hairless patches	0.073	0.033	0.162	7.862	5.168	11.962
Lesions/swellings	0.405	0.200	0.817	10.073	4.941	20.537

*=P<0.05; **=P<0.01; ***=P<0.001; n.s.= P>0.05

There was a higher likelihood to find these skin alterations on animals housed on FS and the same trend was observed for bursitis. Regardless of the type of floor, the same lesions were more likely to be detected at the end of the fattening period. Estimated odds ratios for nasal discharge were significantly higher for DL than FS bulls and for newly received animals than finished ones.

The low frequency observed for ocular discharge, dyspnoea, diarrhoea, bloated rumen and lameness didn't allow to perform their statistical analysis. Coughing occurrence, recorded as number of events/bull/hour, was not affected by type of floor, but its frequency appear higher during the initial phase of fattening than at the end of it (Table 7).

Table 7 Least square means of bulls coughing

	Type of floor			Fattening phase			
	DL	FS	P	Initial	Final	P	RMSE
Coughing[1]	0.74	0.94	n.s.	1.50	0.17	***	1.32

[1] events/bull/h. ***=P<0.001; n.s.= P>0.05

3.3. BEHAVIOURAL PARAMETERS

The avoidance distance at the feeding rack resulted higher for the animals reared on DL pens and the same parameter was higher when assessed at the beginning of the fattening cycle (Table 8).

Table 8 Least square means for the significant (P<0.05) behavioural parameters

Behavioural Traits	Type of floor			Fattening phase			
	DL	FS	P	Initial	Final	P	RMSE
Avoidance distance, cm	59.07	48.48	***	64.37	43.18	***	33.60
Total Interactions[2]	1.54	2.74	**	0.88	3.41	***	2.34
Agonistic interactions[2]	0.83	1.21	n.s.	0.17	1.87	***	1.77
Cohesive interactions[2]	0.48	1.25	**	0.34	1.39	***	1.24
% Agonistic interactions[3]	57.69	40.75	**	41.31	57.14	**	34.36
% Cohesive interactions[3]	38.99	58.56	**	56.49	41.06	**	33.69
% Mounting[3]	3.31	0.69	*	2.14	2.22	n.s.	5.97
Standing bulls[1]	74.75	59.23	**	57.68	76.31	***	25.16
Feeding bulls[1]	12.81	19.20	n.s.	18.14	13.59	n.s.	19.29
Lying bulls[1]	12.44	21.56	n.s.	23.91	10.10	***	25.00
Ruminating total[1]	6.43	10.23	n.s.	13.25	5.87	***	11.77
Lying down duration, s	5.76	7.00	*	5.80	6.96	n.s.	1.31

[1] % of bulls/tot bulls ; [2] events/bull/h; [3] % events/tot interactions; *** = P<0.001; ** = <0.01; *= P<0.05; ns = P>0.05.

Bulls housed on FS appeared to socially interact more than those on DL, especially for cohesive behaviours recorded either as events/head/hours or as percentage over the total interactions. Bulls on DL on the other hand showed an higher proportion of agonistic interactions and mounting.

The occurrence of both cohesive and agonistic behaviours, measured as number of events/bull/hour, appeared to be more frequent on heavy bulls at the end of the fattening (final phase) than in newly received ones. The percentage of agonistic behaviours over total behaviours was increased at end of the fattening when this type of behaviours prevailed over the cohesive ones (Table 8). On the contrary, newly received beef cattle seem to perform more cohesive than agonistic behaviours at the onset of the fattening cycle.

The proportion of standing animals appeared significantly higher on DL than on FS, while the type of floor did not affect the proportion of feeding, lying and ruminating bulls (Table 8). Lying down transitions duration appeared prolonged for animals housed on slats than on DL (5.76 *vs* 7.00 sec). Compared to the observation performed at the beginning of the fattening, the final phase scans showed an increased proportion of bulls standing (76.31% *vs* 57.68%) and a reduction of the lying ones (10.10% *vs* 23.91%). Even the percentage of animals ruminating 2 hours after feed distribution was reduced at the end of the fattening cycle. There was no difference between the two fattening phases for the duration of the lying down transitions (Table 8). The occurrences of intentions to lie down and atypical lying down events resulted too low to allow to perform their statistical analysis.

4. DISCUSSION

4.1 PRODUCTIVE PERFORMANCES, DIRTINESS AND CLINICAL MEASUREMENTS

Confirming previous findings of Hickey et al. (2002) and Gottardo et al. (2003), even in the present study, DL resulted not to be an adequate system to guarantee beef cattle cleanliness. Deep litter system requires approximately 4 to 6 kg of straw per animal per day (Daeleman and Manton, 1987), but the amount provided in this farm (1.52 kg/head/day) was far below this requirement. When provided with insufficient bedding material, animals become dirty as result of the wet lying conditions. Newly received bulls are more likely to be dirty since they are more frequently lying than animals at the end of the fattening. Newly received bulls are also more susceptible to suffer for infectious disease, such as diarrhoea, that can impair coat cleanliness (Salak-Johnson and McGlone, 2007).

The higher culling incidence observed for FS bulls is consistent with previous studies trend (ITEB, 1983; Cerchiaro et al., 2005; Cozzi et al., 2005; Schulze Westerath et al., 2007), supporting once again the negative effect of this type of floor on beef cattle welfare. Overall morbidity was twice as high in bulls kept on FS than in those kept on straw yards, confirming the findings of Hannan and Murphy (1983). According to the same authors also mortality rate, as result of natural causes, should have been higher in FS pens, but this result was not observed in the present study. As reported by SCAHAW (2001), Vokey et al. (2001), Bergsten (2003), Somers et al. (2003), Sogstad et al. (2005) and Shulze Westerath et al. (2007), bulls kept on FS and or at the end of the fattening cycle are more susceptible to musculoskeletal system pathologies and bursitis and this result was observed also in the present study. The incidence of clinical lameness was instead too low to allow its statistical analysis.

The higher of incidence of respiratory syndromes as cause of culling and the more likely occurrence of nasal discharge observed for DL bulls can be explained by the use dusty litter, that can be easily inhalated, promoting the outbreak of respiratory diseases (Cozzi et al. 2005). Moreover, according to Biet et al. (2005), an organic substrate as the bedding material, could allow an easy multiplication of microorganism, even pathogens, increasing the risk of diseases. Newly received animals are more sensitive than older cattle to stressful situations which can suppress their immune system, promoting the outbreak of pathologies (Salak-Johnson and McGlone, 2007).

Estimated odds ratios for hair and skin damages were significantly higher for FS than DL bulls, confirming the results of previous comparisons (Gottardo et al., 2003; Somers et al., 2005; Schulze Westerath et al., 2007; Tessitore et al., 2009). In this work, bulls skin integrity was more likely to be impaired at the end of the fattening cycle and this may be due to the higher occurrence of agonistic behaviours, that might cause skin damages and wounds .

4.2 BEHAVIOURAL PARAMETERS

The outcomes of the ADF test showed newly received bulls being more fearful than the finished ones. French bulls are weaned and kept on pasture almost until the time of their export to the Italian fattening units (Federici and Rama, 2007), therefore they are likely less used to humans at the onset of the finishing period. At the end of the fattening cycle they are more used to be approached by the stockman and their flight distances decreases (Hemsworth et al., 2000). Bulls housed on bedded floor showed a higher avoidance distance than the FS ones. At this regard though, it must be pointed out that DL pens were twice as much deeper than FS ones and therefore DL animals could have been less used to be closely approached by humans. Waiblinger et al. (2003) found that social licking is increased in cattle groups with minimum avoidance reactions and this is consistent with our results for FS bulls, that showed more cohesive interactions (social liking and horning) than DL ones. Agonistic interactions and mounting were more frequently performed by bulls housed on DL, probably because bedded floor offers a secure foot grip and animals feel more confident to interact even by force. Moreover, in DL pens agonistic competition could have been promoted either by higher number of animals housed per pen or by the narrower space at the manger allowed per head. Bulls housed on FS performed more interactions and cohesive behaviours than on DL, likely as an attempt to cope with a housing systems known to be more unnatural and stressful (Phillips, 2002; Platz et al., 2007).

Cattle observed in the final phase of their fattening cycle appeared more active, performing more agonistic and less cohesive interactions than the newly received bulls. This trend could be explained by the progressive reduction of the space allowance, that leads disputes (SCAHAW, 2001). The decreasing space allowance could also justify the higher proportion of standing bulls observed in the assessment carried out at the end of the fattening. The proportion of animal standing appeared higher on DL, probably because bulls were unmotivated to lie down on a litter hygienically too poor. A higher proportion of ruminating bulls observed in the early fattening could have been promoted by the fact that space allowance wasn't constraining yet and the relative mutual disturbance among pen-mates with the occurrence of agonistic interactions was still low. Consistently with what reported by Wechsler (2007), Platz et al. (2007), Absmanner et al. (2009) and Tessitore et al. (2009), lying down sequences duration resulted longer for FS than DL bulls as the consequence of a less comfortable housing system. Previous studies reported also a higher frequency of abnormal or unsuccessful lying down sequences for bulls housed in FS pens (Ruis-Heutink et al., 2000; Platz et al., 2007; Gygax et al., 2007). These findings were not confirmed in the present research since the occurrence of abnormal lying down sequences or lying down attempts was too low to allow their statistical analysis.

5. CONCLUSIONS:

This experiment aimed to evaluate the effects of the type of floor on the clinical status, behaviour and performance of beef cattle intensively finished. The results highlighted how the slats affect negatively both pathological and behavioural parameters. Cattle reared on slatted floor are more likely to be culled during the finishing because of locomotory syndromes. The direct contact with an hard and discontinuous surface increases the incidence of bursitis and skin lesions. Young bulls raised on slats were reluctant to perform mounting and other behaviours that required a good balance and an adequate foot grip on the floor. Lying down sequences duration were prolonged to, indicating the loss of confidence that a hard surface can cause to these animals. Bulls kept on straw are exposed to a lower risk of skin alterations, but they can suffer of an unsatisfactory cleanliness when the litter is inadequately managed. On deep litter, the risk of culling is lower than on slats, and it is mainly due to respiratory diseases. In order to further reduce the culling rate, it is therefore advisable to avoid to use of dusty bedding material. Cattle growth performance were not affected by the type of floor and this could explain why many beef producers are still adopting the fully slatted floor in their fattening units.

Regarding the phase of the fattening cycle, younger animals, observed one month after arrival to the fattening unit were more likely to suffer of respiratory disease, probably caused by the stress of adaptation to the new rearing environment. Newly received animals appeared less confident to be approached by humans and performed more cohesive behaviour than finished bulls. At the end of the fattening cycle bulls were more active and aggressive and skin lesions were more frequently observed. This increase in agonistic interactions could be the result of the reduction of space allowance at the end of the fattening.

In conclusion, aiming at improving the welfare of intensive fattened beef cattle, farmers should pay particular attention to pen floor. When using the deep litter, a proper management of the litter is required and it should imply the provision of an adequate amount of bedding material along with its frequent renewal. The use of dusty material should be avoided to lower the risk of respiratory problems. Cattle kept on slats are at higher risk of poor welfare and their discomfort might be reduced by covering the floor with rubber mattresses. Observations carried out at the end of the fattening have shown that space allowance should be increased according to cattle frame and weight. If space becomes a limiting factor, aggressions and negative interactions among pen-mates.are likely to be increased with a negative impact of farm productivity.

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II - Effects of pen floor and class of live weight on behavioural and clinical parameters of beef cattle

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1.INTRODUCTION

Nowadays, the farm animal welfare issue is earning a wide importance for the public opinion, as well as for the scientific community. In this context, the European Commission has adopted from 2006 a Community Action Plan on the Protection and Welfare of Animals, that aims at promoting high animal welfare standards in every rearing system of all Member States. Currently many scientific groups are working to find reliable welfare indicators to be used for the main livestock species. Most of young bulls fattened in Italy are imported from foreign Countries, and they arrive to the Italian farms at a wide range of live weights (80-400 kg) (Federici and Rama, 2007). Almost all the Italian beef farms located in the Po Valley adopt an intensive rearing system, with cattle housed in multiple pens on deep litter (DL) or fully slatted (FS) floor (Cozzi, 2007). However, this latter type of pen floor has been hardly criticized by some cattle welfare experts, because it is considered not completely respectful of bulls needs. (EU-SCAHAW, 2001). The aim of this study was to evaluate how pen floor (TF) and class of cattle live weight (WC) may affect behavioural and clinical parameters of young bulls fattened under intensive rearing conditions.

2.MATERIAL AND METHODS

Twenty intensive beef cattle farms were selected for this research, according to the experimental design presented in Table 1. All the animals were imported from foreign

Countries, mainly France and Austria. Every farm was visited once during the first quarter of 2008, in order to assess cattle behaviour and clinical parameters. Each visit considered 2 h of direct observation of the animals housed up to 12 pens to assess the following behavioural parameters: avoidance distance at the feeding rack (Waiblinger *et al.*, 2003), percentage of animals lying, standing or feeding/drinking and the duration of the lying down sequence.

Table 1: Experimental design and average space allowance (mean ± sd).

	Fully slatted (FS)		Deep litter (DL)	
Class of live weight	≤ 350 kg	> 350 kg	≤ 350 kg	> 350 kg
Number of farms	4	6	6	4
Average space allowance, m^2/head	1.9 ± 0.4	3.8 ± 1.0	2.7 ± 1.2	4.4 ± 1.5

The type of interactions between pen-mates and their frequencies were also recorded. Displacement, chasing, head-butt and fighting were considered as negative interactions, whereas horning and social licking were considered as positive. The clinical measurements consisted on the evaluation of the presence/absence of some pathological and less healthy conditions, such as skin hairless patches and lesions, overgrown claws, thinness, coughing, nasal and ocular discharge, dirtiness and lameness. All behavioural and clinical measurements were carried out in all the farms in the same order by the same assessor. Statistical analyses were performed using the General Linear Model procedure (SAS, 1990) for behavioural traits and coughing. The model included the effects of type of floor and class of live weight and their interaction. For lying down duration, the model considered only the effect of the floor type, since this parameter was recorded only in heavier class of animals. All the remaining clinical traits were recorded as dichotomous variables and they were analysed by Logistic Regression procedure (SAS, 1990). Factors were compared using the Wald Chi-Square Test. The threshold of statistical significance was set at $P<0.05$ for all the variables.

3.RESULTS AND CONCLUSIONS

Type of floor did not affect all behavioural traits, except for lying down duration, which was longer for FS than DL bulls (Table 2). This result was consistent with what reported by Wechsler (2007). Considering the effect of the class of live weight, the frequency of feeding/drinking was reduced in heavier bulls and this trend confirmed previous results reported by Gottardo *et al.,* (2004). The percentage of lying was higher for heavier bulls and this behaviour could be a consequence of the increased space allowance (Table 1).

Table 2: Least square means of bulls behavioural parameters and coughing.

	Type of floor		Live weight class		Significance		
	FS	DL	≤ 350 kg	> 350 kg	TF	WC	RMSE
Behavioural traits:							
Feeding/Drinking[1]	15.5	14.20	19.05	10.67	ns	***	15.25
Lying[1]	42.2	44.48	39.09	47.59	ns	*	26.57
Displacement[2]	0.09	0.05	0.13	0.01	ns	***	0.19
Chasing[2]	0.05	0.02	0.07	<0.01	ns	**	0.16
Horning[2]	0.60	0.82	0.44	0.98	ns	**	1.34
Avoidance distance[3]	41.0	44.8	30.4	55.3	ns	***	56.53
Duration lying down[4]	5.71	4.31	-	-	***	-	1.70
Clinical traits:							
Coughing[2]	1.48	1.66	2.07	1.07	ns	***	1.40

[1]% of bulls; [2]events/bull/h; [3]cm; [4]sec; *** = *P<0.001; ** = <0.01; *= P<0.05; ns = P>0.05.*

Space allowance could also justify the reduced frequency of negative interactions and the increasing of horning behaviour (Table 2). Type of floor and class of live weight did not affect the occurrence of head-butt, fighting and social licking (0.57±1.49; 0.02±0.18; and 0.59±1.04 events/bull/h, respectively). The avoidance distance test showed heavier bulls being more fearful than lighter ones (Table 2). Most of the light animals raised in the Italian fattening units are weaned artificially and therefore they are used to be approached by humans. French bulls, which represented a large portion of the animals included in the heavy weight class, are instead weaned and kept on pasture almost until the time of their export (Federici and Rama, 2007). Clinical signs of respiratory diseases (coughing and nose discharge) were not affected by the type of pen floor, whereas they were increased significantly for light bulls (Tables 2 and 3). These animals are more sensitive than older cattle to stressful situations like transport, regrouping, thermal stress, change of housing system, which can suppress their immune system (Salak-Johnson and McGlone, 2007); under these circumstances, the outbreak of respiratory disorders and mycosis is increased. Consistent with these findings, the likelihood of occurrence of hairless patches was increased in light bulls (Table 3). Estimated odds ratios for hair and skin damages and lameness were significantly higher for FS than DL bulls, confirming the results of previous comparisons (Gottardo *et al.*, 2003; Somers *et al.*, 2005). On the other hand, in accordance with Gottardo *et al.*, (2003), bulls cleanliness was more likely to be impaired on bedded floor. Heavy bulls spent more time lying down (Table 2) and this may have increased their likelihood of being dirtier. The low frequency observed for the other clinical traits (overgrown claws, ocular discharge, diarrhoea, thinness, bloated rumen) did not allow to perform their statistical analysis.

Table 3: Estimation of the odds ratios for the clinical parameters assessed (P<0.05).

	Wald test Confidence limits at 95%					
	Type of floor (DL *vs.* FS)			Live weight class (≤ 350 *vs.* > 350		
Effects	Odds	Minimum	Maximum	Odds	Minimum	Maximum
Nasal	ns	ns	ns	1.63	1.04	2.53
Hairless	0.48	0.37	0.62	1.58	1.21	2.05
Skin lesions	0.14	0.09	0.22	0.55	0.37	0.82
Dirtiness	4.39	2.92	6.61	0.33	0.22	0.51
Lameness	0.22	0.06	0.79	ns	ns	ns

Results of the present study showed that in comparison with DL, FS floor has a limited effect on beef cattle behaviour, while it is expected to increase the incidence of integument alterations and lameness. However, DL cannot be considered the best solution for intensive housing of beef cattle unless its renewal is a routine practice of the farm management. Regarding bulls live weight, negative interactions among pen-mates are more frequent in lighter and younger animals, which are also more sensitive to respiratory disorders. In heavier bulls, regardless of the type of pen floor, an adequate space allowance can be an effective strategy to lower agonistic interactions as well as the risk of disease occurrence.

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III - Alternative solutions to the concrete fully slatted floor for the housing of finishing beef cattle. Effects on growth performance, behaviour and health status

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1.INTRODUCTION

The adoption of the slatted floor housing system in beef cattle farms has become popular since 1980. Despite the higher initial cost when compared with the conventional littered barn, this system allows to reduce the cost for bedding material and related labour. Moreover, the slatted floor system allows to increase stocking density reducing the production cost per animal unit. However cattle appear not to be physically and mentally comfortable when housed on slats, because the hard floor surface makes them feel a natural aversion and fear to walk and rise on it. As a result, cattle do not perform some extreme behaviours as often as they would in an outdoor situation. Concrete slats that are too roughened to prevent slippage can wear hooves excessively. When instead slats surface is too smooth, it becomes slippery increasing the incidence of legs and claws injuries incidence (Dumelow and Albutt, 1988).

Most of the studies on pen floorings delve into dairy cows herds, where the result of the housing discomfort are well noticeable because of the drop in milk yield (Kremer et al., 2007), hence in an economic loss. The adoption of an alternative floor, easy to manage and comfortable for animals at the same time, is becoming a need, and perforated floor and rubber covering have been proposed and tested as slats substitutes. Research concerning the use of rubber coated slatted flooring in beef finishing facilities is however still limited. This is mainly due to economical reasons related to the cost of this type of floor as well as to the short life span spent by beef cattle in the finishing units. Cattle behavioural benefits related to the use of a perforated rubber mats were reported by many authors (Lowe et al., 2001b; Mayer et al., 2005). In her study, Benz (2002) considered the effect of yielding rubber floors on slatted passageways on claw health and behaviour of dairy cows: it resulted that steps on rubber floor were longer and more similar to those on pasture and cows appeared to express more natural behaviours. Telezhenko and Bergsten (2005) confirmed the same result in their work, underlining how a rubber floor can improve dairy cows locomotion and gait, irrespectively of the presence of lameness.

Aiming at improving the knowledge on potential alternative solutions to the concrete fully slatted floor to be adopted in beef cattle fattening units, the study evaluated the effect of three different types of pen floor (FS, Fully-slatted floor; FP, Fully-perforated floor; RM, Fully-perforated floor covered by rubber mattress) on growth performance, behaviour and health status of young bulls fattened under intensive rearing conditions.

2.MATERIAL AND METHODS

2.1 ANIMALS, HOUSING AND MANAGEMENT

The study was carried out in a medium-large size farm with a availability of about 1,600 fattening places, located in the Po valley (Italy). All bulls fattened in this farm are purchased and imported from foreign countries (France, Ireland, Belgium mainly) and their live weights and ages at arrival may vary depending on the genetic type (on average 350-400 kg and 10-12 months of age). Bulls are then fattened till 18 months of age and the ideal slaughter weight of about 650-750 kg. Bulls growth performance, health and behaviour were investigated during a 7 months period from September 2009 to March 2010, comparing 3 different pens floor solutions: Fully-slatted floor (FS); Fully-perforated floor (FP); Fully-perforated floor covered by rubber mattress (RM). Two batches of 24 young bulls each were considered; the former was made of Irish crossbreed, the latter of French Limousine. Prior to the housing into the finishing pens, the animals of each batch were weighted and equally allotted in three group of 8 bulls each according their live weight. The three groups of each batch were then housed in three pens with different floor, for a total of 6 boxes. The experimental pens had a size of 5.50 x 4.45 m, two of them had a traditional slatted floor, made with concrete slats 100 cm long and 12.5 cm thick, split by a 3 cm gap. The second pair of pens had a perforated floor, made by drilled concrete panels that have 70 holes/m^2 with a diameter of 6.5 cm. In the third pair of pens, the previously described perforated floor was covered by a rubber mattress, 2 cm thick, designed to match the gap profile of the concrete slatted floor elements below. These rubber mats (Type Apollo 20/0) manufactured by Eurosteinit S.r.l.- Italy have a hammerblow profile surface to enhance grip, the underside profile is rubber studded and the edges are profiled to allow for a grooveless surface. The 6 experimental pens were located in the same closed barn and they were equipped with two pressure bowls for water provision. Each pen had a space allowance of 3 m^2 and a space at the manger of 70 cm. The young bulls were fed *ad libitum* once daily in the morning a corn based total mixed ration (Table 1).

Table 1: Feed ingredients and chemical composition.

Ingredients	% DM
Corn silage	44.9
High moisture corn	16.9
Corn meal	15.2
Soybean meal 44	13.0
Beat pulps	3.5
Wheat brans	4.7
Vitamin-mineral premix[a]	1.9
Chemical composition	**mean ± SD**
Dry matter (%)	50.6 ± 2.9
Crude Protein (% DM)	13.3 ± 0.8
Diethyl ether extract (% DM)	3.1 ± 0.2
Ash (% DM)	6.8 ± 0.3
NDF (% DM)	31.6 ± 1.9
NSC[b] (% DM)	45.2 ± 1.9
UFV (/kg DM)***	0.94

[a]Ingredients (per kg): Ca, 180 g; Na, 104 g; P, 70 g; Mg, 35 g; Zn, 3400 mg; Mn, 1500 mg; Fe, 200 mg; Cu, 200 mg; I, 60 mg; Co, 20 mg ; Se, 10 mg; Mb, 10 mg; vitamin A, 1,000,000 IU; vitamin D, 120,000 IU; vitamin E, 100 mg; vitamin K, 20 mg; choline, 5,000 mg; vitamin PP, 4,000 mg; vitamin B1, 100 mg; vitamin B2, 50 mg; vitamin B12, 0.4 mg ; [b]NSC = Non-structural carbohydrates; ***Unitè Foragere Viande = 76.1852MJ.

2.2 GROWTH PERFORMANCES AND FEED INTAKE

Each animal was weighed twice, at the time of arrival to the farm and at the end of fattening cycle to measure the *Average Daily Gain*. This was calculated as the difference between final and initial live weight, dividing the result by the number of days on feed. The *Feed Intake* per pen was calculated as the difference between the amount of feed distributed in the morning and the residual amount present in the manger 24 hours later, just before the following feeding. This record was carried out on two consecutive days per week during 6 months of animal fattening. The raw weight of the feed eaten by each box has been transformed into Dry Matter on the basis of analysis done on a weekly sample of the food distributed. *Feed Conversion Ratio* was calculated as the ratio between the consumption of dry matter and the average daily gain of each box. All the feed samples collected during the study were analyzed at the chemical laboratory of the Animal Sciences Department, University of Padua. The analysis considered the content of dry matter, crude protein, ash, lipid according to AOAC methods (2000). Diet fiber content was instead determined by the method of Van Soest et al. (1991). The net energy content of the experimental diet was calculated as Unitè Forager Viande, on the basis of values proposed by INRA (1988) for the various food constituents.

2.3 BEHAVIOURAL PARAMETERS

In order to assess the behaviour of bulls during the experimental period, each batch of animals was observed twice. The first evaluation (Initial Phase) was carry out one month after the restocking, when all the animals had an estimated weight lighter than 500 kg. The second observation was performed near the expected slaughter time (Final Phase), when the estimated live weight exceeded 600 kg. Each of these behavioural observations had a duration of 8 hours and began immediately after the morning feed distribution (9:30-10 am). During each observation session the three experimental pens belonging to the same batch were assessed by three different observers. In order to avoid a bias effect, after each hour of observation on the same box, the observers proceeded to shift their position, assessing then a different pen. The assessors position during this observation was always on top of an elevated platform placed in the middle of the feeding allay, allowing a whole view of the cattle housed in the experimental pen. To allow an easy identification of animals and an easier distinction between pen-mates, the day before an observation, bulls housed in the three pens of the same batches were tagged, painting a sequential number (1-8) on both the hindquarters of each animal, using a livestock colour spray. Behavioural assessments were performed adopting the scan-sampling technique (Martin and Bateson, 1993) with a 5-minute interval between one scan to the following one. The scan turns out to be a snapshot of the box that states the individual activities of each individual who is supposed to be made for its entire duration (Maekawa et al., 2002). The sum of the number of scan the animal was recorded to perform a certain activity allows to describe the incidence of this activity over 8 hours. The behaviours observed were related to the position the animal adopted (station, recumbency), and the activity that each animal performed at the time of scan (eat / drink, ruminating, resting). The resting position was recorded, classifying it as sternal recumbency with all four legs folded above the body, sternal recumbency with one or both front legs stretched out, and lateral recumbency, with all four limbs stretched. During the whole period of observation, the occurrence of some other activities, that could be not recordable as scan sampling data because performed just for short period of time, were recorded not individually, but in a pen level. These behaviours were detected, by the method of behaviour sampling (Martin and Bateson, 1993) and are: allo-grooming, slipping, fights, and unsuccessful attempts to lying down. In order to obtain more info about the resting comfort and animal confidence to move, the duration of both lying down and rising up transitions were recorded using a stopwatch, every time they were performed.

2.4 HEALTH STATUS AND CLEANLINESS SCORE

After both the behavioural observations, each animals was then assess for signs of low health status, as such as the presence of lameness, skin lesions, carpal bursitis, overgrown claws and nose discharge. These parameters were recorded as presence/absence by the same person during the whole project. A coat cleanliness score was then detect taking into account just one side of the animals, and recording it dirty when more than 25% of the side was covered by thick manure. Cleanliness and lameness, and nose discharge evaluation was based on Welfare Quality® protocol for beef cattle (2009). The occurrence of skin lesions were recorded when the animal coat had wounds, hairless patches or abrasions, regardless of the etiologic causes. Lastly swollen carpal joint findings were considered as macroscopic sign of bursitis and its presence was then in that way recorded. Claws abnormalities were recorded as a binary variable; when at least one claw was overgrown or deformed, the status = overgrown was recorded.

2.5 STATISTICAL ANALYSIS OF DATA

The production performances of animals were analyzed using SAS (1990) linear model PROC GLM, setting the effect of type of floor (FS vs FP vs RM) and the effect of assessment (Initial and Final). Feed intake and feed conversion rate were analyzed using a linear model and considering as effects the floor type, pen within floor, week, and testing the interaction between the type of flooring and the week of fattening. In these analysis pen was considered the experimental unit.

The behaviour records collected during both the observations were processed using a linear model that considering as effects the floor type and assessment and their interaction. In all the analysis a minimum threshold of statistical significance of $P < 0.05$ was adopted. Clinical parameters as well as cleanliness were analyzed using SAS logistic regression procedure.

3.RESULTS

3.1 GROWTH PERFORMANCES

The mean live weight at the beginning of the experiment was 426 ± 54 kg: this large standard deviation was due to high heterogeneousity among animals and batches too, being bulls imported from Ireland heavier. The duration of the fattening cycle results to be about six months (175 ± 7 d), with no differences between the three thesis. Types of floor resulted to significantly affect the growth performance of animals: bulls reared on rubber mattress appear to have almost 0.2 kg higher average daily gain compared with bulls on slats, while perforated floor effects resulted intermediate between FS and RM

(Table 2). Live weights, feed intake and feed conversion rate did not differ significantly among the three animal groups (Table 2). The statistical model for feed consumption during the whole trail report a significant effect of week of testing (P <0.001), probably due to climate variability.

Table 2: Live weight, feed intakes, daily gain and feed convertion ratio of young bulls housed in multiple pens with different type of floor

	Type of pen floor[1]				
Item	FS	FP	RM	RSME	*P*
Live weight, kg:					
- Initial	409.5	450.4	417.8	13.0	ns
- final	623.1	678.6	663.6	35.0	ns
Feed intake, g DM/d/bull	7.96	9.16	9.17	0.38	ns
Average daily gain, kg	1.19b	1.27ab	1.37a	0.18	*
Feed Convertion Ratio	6.65	7.53	7.23	0.92	ns

1FS = fully-slatted floor; FP = fully-perforated floor; RM = fully-perforated floor covered by rubber mattress; * P< 0.05; ns: not significant (*P* > 0.05)

3.2 BEHAVIOURAL PARAMETERS

The statistical results concerning the behaviour records collected by scan sampling method are summarized in Table 3.

Table 3. Effect of floor type and weight of animals on least square means for time (min) spent by bulls performing the listed behaviours during the 8 hours scan sampling observation

	Type of floor				Assessment			
	FS	FP	RM	P	Initial	Final	P	RMSE[1]
Feeding/drinking (min)	51.9b	51.9b	63.0a	*	54.0	57.2	ns	15.4
Ruminating (min)	61.6	58.3	63.3	ns	69.5a	52.6b	*	25.8
Position:								
Standing (min)	252.4b	245.2b	306.5a	***	266.4	269.7	ns	45.8
Standing (% time/8 hours)	52.58b	53.81b	63.85a	***	59.83a	53.66b	*	10.31
Recumbency (min)	227.60b	221.70b	173.51a	***	192.79b	222.41a	*	49.49
Sternal (% time/time in recumbency)	54.01b	56.84b	73.84a	**	72.84a	50.28b	***	18.51
Legs extended (% time/time in recumbency)	34.66a	34.57a	19.11b	**	20.48b	38.42a	***	15.24
Lateral (% time/time in recumbency)	85.61	89.49	20.15	ns	54.92	75.25	ns	127.82

FS: Fully slatted floor; FP: Fully perforated floor; RM: Rubber mattress; ***= P<0.001; **= P<0.01; *= P<0.05; ns: no significance (*P* > 0.05)

There was a significant effect of the type of floor on the activity and resting behaviour of bulls observed during this trial, but FS and FP floors resulted not to be so different. Animals housed on rubber mattress flooring showed an increased activity, inferable by the longer time that these animals are used to spend standing (both expressed as minutes than percentage of time over the whole observation) and feeding and drinking too. These animals spent consequently a shorter time resting, but they appear to prefer to lie in sternal position with all the legs bent below their body compared with bulls housed on both concrete floors. When housed on FP and FS hard surfaces, bulls besides appear to spend more time resting with one or both the front legs extended. No significant differences between the three types of floor were found concerning the lateral recumbency, scarcely performed, as well as for time spent ruminating. Significant difference were observed also comparing the results recorded at Initial phase of the fattening cycle with the Final one (Table 3). Just received animals appeared to spend more time ruminating and standing, while at the end of the fattening period the same bulls resulted to prefer resting with forelegs extended more frequently than in the initial phase.

The results of the statistical analysis on frequencies of the short duration behaviours detected by the behaviour sampling observation are shown in Table 4.

Table 4: Least square means for behavioural parameters recorded as frequencies and duration during behaviour sampling observation

	Type of floor				Assessment			
	FS	FP	RM	P	Initial	Final	P	RMSE
Lying down attempts[1]	17.3a	10.3ab	1.0b	**	10.2	8.8	ns	4.6
Slipping[1]	52.0a	16.5b	7.3b	**	27.5	23.0	ns	11.8
Mounting[1]	4.0b	8.8b	27.0a	**	18.8a	7.7b	*	6.9
Fighting[1]	8.5	9.0	19.3	ns	7.0	17.5	ns	8.8
Social licking[1]	95.0	84.8	63.5	ns	76.0	86.2	ns	35.8
Lying down duration[2]	5.85a	5.36ab	4.67b	**	4.99b	5.60a	*	1.90
Rising up duration[2]	3.31	3.28	3.41	ns	3.17b	3.50a	*	0.89

[1]= number of events/8 hours observation; [2]= sec; FS: Fully slatted floor; FP: Fully perforated floor; RM: Rubber mattress; ***= P<0.001; **= P<0.01; *= P<0.05; ns: no significance (*P* > 0.05)

Animals housed on FS resulted to perform more frequently unsuccessful lying down attempts compares to RM; in addition they were more prone to incur in slipping events than bulls housed either on perforated floor or on rubber covered floor. Mounting events resulted to be more frequent on RM pens compared to FP and FS. The mean time required to perform the lying down transition was longer for FS than for RM bulls while it was intermediate for RM one. Type of floor appeared not to affect fighting and social licking frequencies neither the duration of the rising up sequence. Regarding the time of the assessment (Table 4), mounting appeared to be less frequently performed by bulls at the end of the finishing compares to the initial one, while both lying down and rising up transitions duration resulted longer in the second assessment. The number of transitions performed by a single bull during the 8 hours of observation was affected just by the type of floor (Table 5).

Table 5: Estimation of the odds ratios for the significant (p<0.05) frequently performed transitions.

	Wald test confidence limits at 95% Type of floor (FS vs RM)			Wald test confidence limits at 95% Type of floor (FP vs RM)		
	Odds Ratios	Min	Max	Odds Ratios	Min	Max
Frequence of transitions	0.245	0.081	0.738	0.168	0.056	0.506

FS: Fully slatted floor; FP: Fully perforated floor; RM: Rubber mattress.

The likelihood to performs frequent transitions (more than 4 bouts) resulted to be higher for bulls housed on rubber mattress floor than on both the hard concrete floors. No effects of the assessment phase were found on frequencies of transitions and on the other behavioural parameters recorded during the behaviour sampling observation.

3.3 HEALTH STATUS AND CLEANLINESS SCORE

The low occurrence of most of the health problems recorded during the trial (nasal discharge, lameness, bursitis, skin lesions) didn't allow to perform their statistical analysis. Just overgrown claws occurrence resulted to be affected by both type of floor and assessment timing (Table 6). The likelihood of occurrence of overgrown claws was increased in bulls housed on rubber mattress floor than on fully slatted and on fully perforated (2.8 and 16 times respectively). Odds ratio for overgrown claws were significantly higher when bulls when assessed in the final phase of their fattening period.

Table 6: Estimation of the odds ratios for the significant (p<0.05) overgrown claws occurrence

	Wald test confidence limits at 95% Type of floor (FS vs RM)			Wald test confidence limits at 95% Type of floor (FP vs RM)			Wald test confidence limits at 95% Assessment (Final vs Initial)		
	Odds Ratios	Min	Max	Odds Ratios	Min	Max	Odds Ratios	Min	Max
Overgrown claws	0.354	0.106	0.983	0.062	0.007	0.513	4.085	1.224	13.636

FS: Fully slatted floor; FP: Fully perforated floor; RM: Rubber mattress

4. DISCUSSION

4.1 GROWTH PERFORMANCE

Bulls reared on Rubber Mattress resulted to have an higher Average Daily Gain, even if they resulted to be more active and therefore more prone to spend energy for standing and locomotion. This result disagreed with Lowe et al. (2001a) findings, where no differences were found due to type of flooring. This improved growth performance were not due to the Feed Intake that was similar among types of floor. However comfortable environmental and housing conditions are known to be able to improve cattle welfare, and indirectly could boost their production performance (Phillips, 1993). Feed Conversion Ratio resulted similar among the thesis, confirming Lowe et al. (2001a) findings. On average, FCR was higher than the values (6.14) calculated by Cozzi and Gottardo for French bulls slaughtered at average lighter live weight (612 kg) in a previous study (2005).

4.2 BEHAVIOURAL PARAMETERS

The type of floor was found not to affect the time spent ruminating by the bulls over the whole period of observation. This activity was performed for about 61 min and this value was lower than that observed by Cozzi and Gottardo (2005) on Limousine in 8 hours after feed distribution observation (83 min). The observation was carried out during the daylight hours and during this time of the day bulls resulted to prefer a standing position confirming the findings of Cozzi and Gottardo (2005). Rubber mattress covered floor seemed to improve bulls comfort when they were standing, since they appeared more active increasing feeding/drinking and mounting events. In theory, this increased time spend standing and socially interacting should have negatively affected cattle growth and productive performance, because of extra use of energy. Mounting is an important behaviour and is often performed by bulls in order to establish the inner hierarchy among pen-mates. Previous studies showed that cattle reduced mounting and active social interactions when the floor surface doesn't guarantee an adequate grip to the foot (Gygaz et al., 2007; Mayer et al., 2007; Absmanner et al., 2009). The positive effect of RM as alternative solution to concrete floors had been reported in recent studies (Ruis-Heutinck et al., 2000; Lowe et al., 2001b; Mayer et al., 2005; Gygax et al., 2007; Absmanner et al., 2009) and could be attributed to the reduction of the risk of falls and consequently the increased confidence of the animal to perform natural behaviours and social interactions, especially with regard to the range of activities involving extreme movements. Bulls appear to individually prefer rubber mattress to concrete slatted floor (Lowe et al., 2001b), even though the straw bedding appears to be their prime choice, as long as properly managed. As reported by Absmanner et al. (2009), the soft rubber surface seems to allow a great confidence and comfort to walk along with a good foot grip that can justify the increased transition frequency as well as the reduction of unsuccessful lying down transitions and slipping frequencies. The higher number of transition bouts observed on RM largely corresponds to what is described as typical for cattle (Absmanner et al., 2009). Fully slatted floor is considered an uncomfortable type of floor for cattle by many authors (Mayer et al., 2007; Platz et al., 2007; Absmanner et al., 2009). The results of this trail are consistent with these previous findings, cattle on FS had a higher risk slip and preferred to adopt lying position for a longer time. Even the duration of the lying down sequences appeared longer, being the transitions on a slippery floor potentially traumatic and painful and more energy expensive (Buchwalder et al., 2000; Lowe et al., 2000; Mayer et al., 2005, 2007; Platz et al., 2007; Absmanner et al., 2009). Bulls housed on FS and FP resulted to spend more time lying compared to RM, and the most performed recumbency position were the sternal ones with a single or both forelegs stretched out, strategy that can allow some relief to the carpal joints (Absmanner et al., 2009). This assumption is supported by observations made on dairy cows that have shown an increasing trend of animals lying with limbs away from the body when housed in cubicles with mattresses or hard concrete floor compared to alternative solutions more soft and comfortable (Haley, 2000). Bulls housed on RM preferred a sternal recumbency position with all legs banded below their body likely because the soft rubber surface guarantees an higher resting comfort. By adopting this lying position, bulls also limit the risk for their legs to be trampled and stamped on by pen-mates. As expected, the fully lateral recumbency position resulted rarely performed since adult ruminants adopt this lying position only for a few minutes because of rumen activity and eructation impediment (Bell, 1972). Both observation sessions were carried out in wintertime and the thermal discomfort of the bulls exposed the low environmental temperatures could further promoted the rare adoption of the lateral position during resting. Gonzalez-Jimenez and Blaxter (1962) and Brunsvold et al. (1985) reported that in a cold environment calves prefer resting with their legs curled under the body to save energy losses.

Bulls assessed at the beginning of the fattening cycle spent more time standing and performed mounting behaviours more frequently than in the final phase, probably because of the need to establish a defined hierarchy status within the pen (Mohan Raj et al., 1991). Consistent with Absmanner et al. (2009), as compared to the initial observation, at the end of the fattening bulls preferred resting in sternal position with forelegs extended. This behaviour could have been promoted by the heavy weight of the bulls since it allows a wider distribution of animals' body weight during lying with a consequent relief the limbs joints. The large body frame could even explain the longer duration of both lying down and rising up transition sequences compared to the initial phase. Despite the prolonged lying observed at end of the fattening, bulls lowered the time spent ruminating probably as consequence of a reduction of the space allowance caused by their large body frame. Under a limiting space, mutual disturbance among pen-mates is supposed to be increased and the synchronization of their feeding activity could likely be reduced.

4.3 HEALTH STATUS AND CLEANLINESS SCORE

The low frequency observed for the most clinical traits did not allow to perform their statistical analysis. However, according to the literature, lameness as well as skin lesions localized in the legs are supposed to be more frequent in FS bulls (Gottardo et al., 2003; Somers et al. 2005; Platz et al. 2007 and Schulze Westerath et al., 2007). Poor floor quality is considered a main risk factor for lameness and traumatic injuries in cattle (Cook et al., 2004; Telezhenko et al., 2009). The system of cleanliness evaluation adopted in this trail was probably not enough sensitive to recognise minimal differences. However, according to Lowe et al. (2001a), rubber coating and perforated floors are usually involved in a poor manure draining trough the slots leading to dirtier cattle than the fully slatted floor. Regarding claw health, in the present study beef cattle kept on rubberised floorings during the whole finishing period showed to be at greater risk of overgrown claw. This is consistent with Platz et al. (2007) and Telezhenko et al. (2009) who found that cows housed on rubber are more likely to required trimming after some months, because of insufficient hoof wearing. As in the present study, Italian young bulls are typically slaughtered at 18 months of age, after a 6-8 months of intensive finishing. This period is too short to suffer of clinical lameness, but if the cycle were longer, probably the overgrown claws would cause a limb axis alteration and joint overloading, increasing the risk of lameness (Manson and Leaver, 1989; Manske et al., 2002; Dembele et al., 2006).

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IV - Lameness in chronic pen: A Pilot study within 3 Southern Alberta commercial Feedlots

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1.INTRODUCTION

In 2008, in Canada there were 13.18 million cattle and calves, on 86,520 farms and ranches with beef cattle (Agriculture and Agri-Food Canada, 2011). Alberta accounts for approximately 41% of this inventory and together with Saskatchewan raised 70% of Canada's finished cattle production (Canfax, 2011). In order to remain globally competitive, Canadian beef industry should improve practices and recommendations for the care and handling of cattle based on scientific principles. This not only to improve animal health and well-being (Mitchell and Kettlewell, 2008) but also for the economic and political implications. Furthermore the public interest in the welfare of farmed animals and cattle lameness in particular is increasing, within both the dairy and beef industries. In this context, lameness is not only an issue because of the negative effect on public perception of the industry, but also for the negative impact on the cost of production through the increased use of antibiotic treatments, the decreased feedlot performance, the increased cattle mortality and the discounted prices at auctions (Tibbett et al., 2006; DBQA, 2009). Lameness is considered to be one of the most important welfare issues for dairy cows (Flower and Weary, 2008), likely because of the high prevalence and association with pain. However, so far a few scientific studies have assessed the incidence of lameness within the Canadian beef industry and feedlots rearing system and/or the potential causative factors associated with it. A study performed at the Saskatchewan Feed Test Station by Townsend et al. (1989) identified fever (12.9%) and lameness (17.2%) as the most common pathologies in beef bulls. Lameness was associated with higher live weights at arrival to the station and its higher incidence was associated with specific breeds. More recently, reports from Roeber et al. (2001) and the NMCBBQA (2007) indicate that there is evidence of lameness in approximately 30% of cattle at slaughter. In US feedlots, Griffin et al. (1993) reported that lameness accounted for 16% of health problems and 5% of deaths. Approximately 70% of all the cases of lameness were due to feet problems, with other injuries to upper skeleton or major muscles accounting for 15%, swelling of joints accounting for 12% and injection site lesions accounting for only 3% (Griffin et al., 1993). Hypotheses exist regarding the causation of lameness in beef cattle, especially on the role of nutrition and the development of laminitis in feedlot cattle on high energy diets, however some research suggests a role for mechanical influences in the environment (Fjeldaas et al., 2007). It is likely that some mechanical factors could interact with biological processes in the limbs of cattle to increase the likelihood of lameness, like an increased standing time (Galindo and Broom, 2000) or an hard, slipping and/or rough flooring surface as for dairy cattle (Telezhenko and Bergsten, 2005; Epejo and Endres, 2007). All these environmental conditions are more likely to affect animals during some phases of beef cattle life, as during auction sales and transport. However, those studies are mainly focused on cattle ready for slaughter while no works examined the different categories of cattle neither the different points of the rearing process. Determining the process phase during which beef cattle are more likely to be lame should address where and when interventions should be made in order to smooth over the negative effect of lameness on profitability.

Determining the association between environmental factors and increased risk of lameness, as well as what groups are most at-risk, will indicate what pragmatic solutions would have the greatest likelihood of success. All these efforts should increase the public confidence in beef industry's actions aimed to guarantee cattle welfare. The objective of the proposed study are to gather descriptive information about the occurrence of lameness in chronic pens by comparing it with the other health problem that commonly affect feedlot beef cattle. A further goal was to better figure out how lameness influences beef cattle productivity.

2.MATERIALS AND METHODS

Between May and August 2010 lameness issue was studied at 3 different commercial feedlots, all located in Southern Alberta region of Canada. These three feedlots, defined in this work as A, B and C have a different cattle capacity and hospital facilities, summarized in Table 1.

Table 1 Feedlots and hospital pens features

Feedlots	Capacity, n heads	Hospital pens, n	Hospital pen size (mean ± SD)
A	25.000	4	255.3 ± 82.4 m^2
B	10.000	4	854.3 ± 284.0 m^2
C	10.000	2	440.4 ± 1.0 m^2

Cattle suffering of a given health problem or disease are usually moved from the original pen to the hospital one, where they are treated by the feedlot for that diagnosed clinical problem. The ear tag number of processed animals and treatments performed are recorded in the feedlot database, as well as the cause of hospitalization. These animals will be housed in the sick pen till recovery, when they will moved back to the original pen. The number of animals housed in hospital pens at the same time is different, depending on many factors, as season, feedlot crowding status and management, climate and outbreak of epidemic diseases. For the purpose of this study data were collected from each feedlot every two weeks, for a period of 3 months (7 observations) processing both lame and non-lame cattle housed within the chronic pens at the time of the observation. The collection was performed between 08.00 and 12.00 AM, depending on the number of animals.

2.1 BEHAVIOURAL DATA

Gait Scoring

All the animals housed in the chronic pens were gait scored using the 5 point scale reported by Desrochers et al. (2001). Animals were assessed according to the description outlined in Table 2, recording in addition the limb/s affected (fore or hind). The gait evaluation was carried out by a trained assessor during cattle handling, while animals were moved to the working chute, evaluating them while walking in small groups (3-4 heads). Lameness was defined as deviation in gait resulting from pain or discomfort from hoof or leg injuries and disease (Flower and Weary, 2008) and animals having a locomotion score ≥ 2 were here defined clinically lame.

Table 9 Scoring method for lameness taken from Desrocher et al. 2001

Score	Gait abnormality	Description
0	None	Normal gait
1	Mild	Walks easily and readily, bears full weight on foot and limb but has an observable gait alteration, stand on all four limbs, line of backbone normal
2	Moderate	Reluctant to walk and bear weight but does use the limb to ambulate, short weight-bearing phase of stride, rest the affected limb when standing, increased periods of recumbecy. May see arching to backbone
3	Severe	Reluctant to stand, refuse to walk without stimulus. Non-weight bearing on affected limb, “hoops” over limb rather than weight bear, does not use limb when standing and lies down most of the time, backbone arched with caudoventral tip to pelvis
4	Nonambulatory	Recumbent, unable to rise, euthanasia often indicated

2.2 PHYSIOLOGICAL DATA

Cell Blood Count and Body Temperature

Individual blood samples were collected by squeezing cattle into a pneumatic headgate. Approximately 5 ml of blood were taken into vacoutainers tubes via venipuncture from the jugular vein. The samples were then transported to the laboratory, stored at ambient temperature and processed within 5 h for haematological analysis (Reese, 2009).

Erythrocytes (RBC), Hematocrit (HCT), Hemoglobin Concentration (HGB), Total Leukocytes Concentration (WBC), Monocytes (MONO), Granulocytes (GRAN) and Lymphocytes (LYM) were determined from K_3EDTA anti-coagulated blood (6 mL) using an automated haematology analyzer (Veterinary Heska Hematrue Hematology Analyzer) equipped with software for bovine blood. Body temperature was taken via rectal thermometer in order to establish the health status of each animal.

Live weight variation

Animals were individually weighed on a chute scale to detect shrink or rise of live weight between observations. Their individual weight difference (kg) between two or more assessments has been compared taking into account the causation of hospitalization and the occurrence of lameness.

2.3 ANIMAL FACTORS

Animal factors were obtained from feedlots managerial database, including category (steers vs heifers), real or estimate weight at receiving, days on feed, health issue relate to hospitalization and number of treatments. The reason why each animal was treated and hospitalized was classified and recorded in the database by the feedlot employers. Animals that in the feedlot database resulted treated for BRD (Bovine Respiratory Disease), Interstitial Pneumonia and Tracheal Stenosis were considered as generically affected by “Respiratory Disease”. Treatments for “footrot”, limb injuries and joint infections were besides classified as “Locomotion system issue”, whereas ruminal meteorism, rectal prolapses, abscesses, buller steer syndrome, nervous disease, pinkeye, vaginal prolapses and urolithiasis were categorized as “Other pathologies”.

2.4 STATISTICAL ANALYSIS

All statistical analysis was performed using SAS/STAT for Windows (1999). Data were tested for normality using PROC UNIVARIATE and data were then analyzed using the PROC GLM procedure to assess the effects of lameness and other health issues on weight gain, days in feedlot from arrival to the time of the first treatment for a given health problem (DOF), body temperature, n of treatments and blood parameters. Descriptive statistics will be carried out on all data to obtain the relative prevalence of clinical lameness in cattle housed in chronic pens. P-values < 0.05 were considered significant.

3.RESULTS

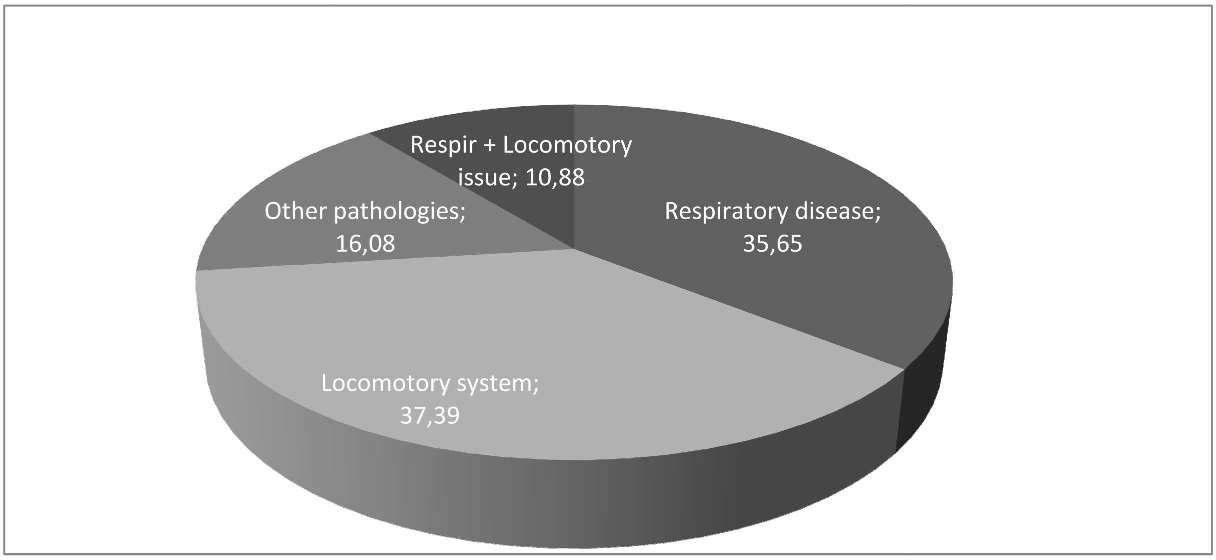
A total of 275 animals were processed and locomotion scored during the 3 months period of study and the 7 assessments that were performed. Some animals were processed and gait scored more than once, sometimes up to seven times, since they were kept in the sick pen for a long time. Table 3 shows the basic descriptive statistics for lameness within feedlot hospital pen. The number of cattle evaluated varied greatly across the 3 farms in the study, probably because of managerial differences on the way sick cattle are treated. On average, most of these animals were steers, while just 12.7 % were heifers. Considering the three feedlots together the mean prevalence of clinical lameness (proportion of cows with locomotion score ≥2) was 37%, and for most of these lame animals the rear limb was the affected one (77.45%).

Table 10 Descriptive statistics for lameness

Feedlots	Animal processed, n	Animal category		Animals processed per observation, mean±SD	Lame animals, n	Prevalence lameness in hospital pen, %	Rear limb lame animals, n	Prevalence rear limb lameness, %
		steer	Heifers					
A	116	106	10	43.57 ± 12.37	38	32.76	31	81.58
B	123	116	7	45.57 ± 10.72	45	36.59	35	77.78
C	36	18	18	20 ± 1.63	19	52.78	13	68.42
Total	275	240	35	36.14 ± 14.92	102	37.09	79	77.45

Feedlot database records allowed us to obtain individual information as arrival date, treatment/s date/s, days on feed and reason of treatment, classifying it in 4 classes: Respiratory Disease (RESP), Locomotion system issue (LOC), Other pathologies (OTHER) and Locomotor and Respiratory Issue associated (LOC+RESP). In Graph 1 is showed that most of the processed animals were treated because of respiratory disease (RESP) and locomotion system (LOC) (35.65 and 37.39% respectively). The association of both respiratory and locomotion disease (LOC+RESP) was reported in the 10.88% of the animals. The remaining 16.08% of processed cattle were treated because of other pathologies (OTHER), not ascribable to any previous classes.

Graph 1 Distribution of class of treatment across processed cattle



Compared to animals with gait score 0 or 1, clinically lame animals resulted to have a lower weight gain between two subsequent observations (14 days period), but this trend was not confirmed by the comparison among treatment categories (Table 4). No differences in DOF were found comparing clinically lame and not lame animals. It resulted that animals affected by an association of both respiratory and locomotory problems (LOC+RESP) were the earliest to be treated on average after 17.28 d. Animals affected by respiratory diseases (RESP) were usually treated for the first time more than 2 months after their arrival to the feedlot. The day of first treatment was extended of a further month when OTHER pathologies occurred (mean = 97.70 d) while DOF for LOC category resulted intermediate (mean = 74.17 d) between RESP and OTHER. Rectal temperature did not differ between lame and not lame animals, neither among treatment categories. Lame animals were treated more frequently than not lame ones (4.01 vs 2.95 times). Animals affected by respiratory disease alone (RESP) or associated (LOC+RESP) appeared to receive more treatments than those treated because of simple locomotion issue (LOC) or other pathologies (OTHER).

Table 411 Effect of gait score and treatment category on least square means for weight gain, days on feed at first treatment (DOF), body temperature and number of treatments.

	RMSE	Gait score			Treatment category				
		P	Lame	Not lame	P	RESP	LOC	OTHER	LOC+RESP
Weight gain inter observation, kg	15.27	**	11.06	18.58	ns	16.39	14.18	17.65	15.25
DOF , d	58.42	ns	69.33	62.62	***	66.81b	74.17ab	97.70°	17.28c
Body temperature, °C	0.45	ns	39.55	39.51	ns	39.56	39.64	39.54	39.53
Treatments, n	2.33	***	2.95	4.01	***	4.37a	2.28b	1.82b	5.44a

*=P<0.05; **=P<0.01; ***=P<0.001; n.s.= P>0.05

Weight gain inter subsequent observations and body temperature were not affected by feedlot effect as well as by the cattle category (Table 5). There was a significant feedlot effect on DOF and number of treatment substantially due to feedlot B that had the lowest DOF and the highest number of treatments. The same variables were not affected by any cattle category effect.

Table 5: Effect of feedlot and cattle category on least square means for weight gain, days on feed at first treatment (DOF), body temperature and number of treatments.

		Feedlots				Cattle category		
	RMSE	P	A	B	C	P	Steers	Heifers
Weight gain inter observation, kg	15.27	ns	37.13	28.95	30.38	ns	37.50	32.33
DOF, d	58.42	**	75.27a	43.57b	79.10a	ns	67.53	60.46
Body temperature, C	0.45	ns	39.56	39.45	39.58	ns	39.54	39.52
Treatments, n	2.33	***	1.36c	5.12a	3.96b	ns	3.139	2.94

*=P<0.05; **=P<0.01; ***=P<0.001; n.s.= P>0.05

Compared to not lame cattle, clinically lame animals had an higher RBC and lower WBC and LYM values in the blood, whereas HCT, HGB, MON, GRAN did not differ according to the gait score (Table 6). Animals treated for locomotory problems (LOC) showed higher RBC, HCT and HBG values than animals treated for respiratory diseases (RESP) while the other two treatment categories (LOC+RESP and OTHER) were intermediate. A significant treatment effect was observed also for WBC, MONO and GRAN due to the highest values recorded in the RESP category. As shown in Table 7, the considered blood parameters were not affected by both feedlot and animal category effects.

Table 6 Effect of gait score and Treatment categories on least square means for blood parameters.

	Units	RMSE	Gait score			Treatment categories					Ref. Range	
			P	Lame	Not lame	P	RESP	LOC	OTHER	LOC+RESP	Low	High
RBC	10^{12}/L	11.52	*	9.18	8.87	**	8.85b	9.34a	8.77b	9.05ab	5	10
HCT	L/L	0.04	ns	0.37	0.37	**	0.35b	0.38a	0.36ab	0.36ab	0.24	0.46
HGB	g/L	13.51	ns	127.64	126.23	**	122.62b	130.13a	124.73ab	125.03ab	80	150
WBC	10^{9}/L	4.20	*	9.72	11.02	***	12.33a	9.74b	9.58b	9.27b	4	12
LYM	10^{9}/L	1.68	*	4.51	5.04	ns	5.12	4.74	4.69	4.35	2.5	7.5
MONO	10^{9}/L	0.34	ns	0.86	0.92	***	1.02a	0.85b	0.79b	0.82b	0	0.8
GRAN	10^{9}/L	3.60	ns	4.15	4.96	**	6.15a	4.15b	4.10b	4.10b	0.6	4

*=P<0.05; **=P<0.01; ***=P<0.001; n.s.= P>0.05; RBC: Erythrocytes; HTC: hematocryt; HGB: Hemoglobin; WBC: White blood cells; LYM: Lymphocyte; MON: Monocyte; GRAN: Granulocytes.

Table 7 Effect of feedlot and cattle category on least square means for blood parameters:

	Units	RMSE	Feedlots				Cattle category			Ref. Range	
			P	A	B	C	P	steer	heifers	Low	High
RBC	10^{12}/L	11.52	ns	9.22	8.92	8.94	ns	9.10	8.90	5	10
HCT	L/L	0.04	ns	0.37	0.38	0.36	ns	0.37	0.37	0.24	0.46
HGB	g/L	13.51	ns	127.34	127.75	125.70	ns	126.52	127.34	80	150
WBC	10^{9}/L	4.20	ns	9.64	10.24	10.53	ns	10.50	9.77	4	12
LYM	10^{9}/L	1.68	ns	4.89	4.55	4.61	ns	4.86	4.50	2.5	7.5
MONO	10^{9}/L	0.34	ns	0.88	0.94	0.85	ns	0.91	0.86	0	0.8
GRAN	10^{9}/L	3.60	ns	3.88	4.75	5.04	ns	4.72	4.39	0.6	4

*=P<0.05; **=P<0.01; ***=P<0.001; n.s.= P>0.05; RBC: Erythrocytes; HTC: hematocryt; HGB: Hemoglobin; WBC: White blood cells; LYM: Lymphocyte; MON: Monocyte; GRAN: Granulocytes.

4. DISCUSSION

This work represents the first attempt to provide a general snapshot about lameness issue in Southern Alberta commercial feedlots system. Lameness is probably underestimated by beef farmers and livestock industry, while public opinion is paying much more attention to this problem. Some studies (Wells et al., 1993; Whay et al., 2003) showed that farmers tend to estimate lameness prevalence levels only at about one-quarter of that estimated by using locomotion scoring. Van Amstel and Shearer (2006) blamed lameness for up to 16 percent of feedlot health problems and to 5 percent of deaths of feedlot cattle, while Stokka et al. (2001) reported lameness to be ranked second in terms of total disease occurrences in feedlot after respiratory diseases. The importance of these two main classes of pathologies is confirmed by our research findings. Considering the 3 feedlots together, the average lameness prevalence in hospital pens was estimated as 37% and this value is consistent with those recorded from the feedlot's databases, where the percentage of animals treated for locomotory problems was 37.4. Lame animals are more likely to spend time lying or standing still, being often too painful for them even the simple walking to and from the feed bunk and water trough (Hassall et al., 1993; Bergsten, 2001; Juarez et al., 2003; Van Amstel and Shearer, 2006). Therefore, feed and water intake are likely to be reduced in lame cattle as well as growth performances (Van Amstel and Shearer, 2006). A report from Nebraska University on lameness in feedlot cattle indicated that in lame animals the gain over their in-weight after 85 days on feed was less than 5 kg (Griffin et al., 1993). A similar but not so severe trend was observed in the present study, where lame animals had a significant drop in the inter observation weight gain as compared with cattle recovered in the sick pen for other health problems. Moreover, an insufficient water and feed intake could also explain the higher RBC, HTC and HGB values recorded in the blood of LOC cattle as a consequence of a slight dehydration (Weiss and Wardrop, 2010). Conversely, LOC treated cattle resulted to have lower values for white cell components (WBC, MONO and GRAN) than animals treated for respiratory diseases likely because these pathologies more frequently turn into a generalized disease that stimulate an immune response. In agreement with a previous study by Van Amstel and Shearer (2006), the rear limbs were more frequently affected by lameness. Rear limbs are involved in propulsion, which causes stress and friction. Lameness is a multifactorial problem and it may relate to feeding and nutrition, housing conditions, environmental factors as well as to management practices (Van Amstel and Shearer, 2006). In addition, the feedlot system by confining cattle in a restricted space, increases the exposure of feet to manure slurry, mud and moisture, especially during periods of frequent rainfalls. This increases potential for the development of infectious skin disorders of the foot (digital and interdigital dermatitis) and heel horn erosion (Van Amstel and Shearer, 2006). The more frequent pathologies involving lameness in feedlot cattle are footrot, laminitis, injuries and sometimes *Mycoplasma bovis* infection (Stokka et al., 2001). This bacteria could be involved in clinical cases when both respiratory and lameness signs are reported. Mycobacterium bovis is known to develop 7 to 14 days after an initial stressor such as transport and arrival to the feedlot. This time is comparable to the mean time at first treatment (17 d) recorded for the animals hospitalized because of LOC+RESP association. In addition, this pathogen is very difficult to be treated and requiring repeated treatments (Currin et al., 2009). At this regard, the results of our study showed RESP and LOC+RESP animals received more treatments in comparison with cattle affected by the other categories of disease. Animals classified within RESP and LOC treatment categories had similar DOF but differed for the number of treatments required being lower for LOC ones. Respiratory disease is known to be the main health issue in feedlot cattle (Stokka et al., 2001), because high infectivity and related economic losses since it normally requires a prolonged therapy. In this work, the occurrence of other pathologies like waterbelly, prolapses and bloated rumen was more frequent in a middle-late stage of the fattening cycle, when cattle were on farm for more than 3 months. The related number of treatments was the lowest likely because most of these health problems are considered of minor importance by the stockmen.

5.CONCLUSIONS

This study underlined the high prevalence of lameness in feedlot cattle housed in sick pens. In several commercial farms the high incidence of lameness could be lowered through the adoption of low stress cattle handling practices and/or by building and maintaining properly designed facilities. To reduce the use of electric prods, to minimize whistling and shouting, to identify and repair any protruding objects in handling facilities likely cause injury, to provide good footing leading within the processing and to place rubber mats at squeeze chute exit are all simple solution capable to low lameness prevalence in feedlot cattle. Along with the growing public concern, farmers' interest towards the reduction of lameness problem in feedlot cattle should be driven by the economic losses due to impaired growth performances, increased early culling and additional costs for medical treatment. Last but not least, the introduction of an action plan to reduce lameness as well as other risk factors for beef cattle welfare might be a way to promote the Canadian beef industry in future trade agreements with international partners such the European Union particularly addressed towards welfare friendly production system.

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3.CONCLUSIONS

This thesis aimed at evaluating the effects of the type of pen floor on the clinical status, behaviour and performance of beef cattle intensively finished. The results highlighted how the use of the fully slatted floor affects negatively both pathological and behavioural parameters. Cattle reared on slatted floor resulted more likely to be culled during the finishing because of locomotory syndromes, while on deep litter the risk of culling is lower and it is mainly due to respiratory diseases. The direct contact with an hard and discontinuous surface increased the incidence of bursitis, hair and skin lesions and lameness. Bulls kept on straw were exposed to a lower risk of skin alterations, but their cleanliness has likely shown to be impaired when exposed to an inadequate litter management.

Among potential alternatives to the slats, cattle growth performance result to be improved when rubber coated floor was compared with other discontinuous flooring. Bulls kept on rubber significantly increased their growth performance, despite being more active. On the other hand, beef cattle housed on rubberized floor were more inclined to suffer because of overgrown claws, due to an insufficient wearing of the hoof when they're kept for a long fattening period. As regards to cattle behaviour, young bulls raised on slats were reluctant to perform mounting and other behaviours and movement that require a good balance and an adequate foot grip on the floor. The rubber covering greatly reduced some abnormalities such as slipping and unsuccessful attempts to lying down, allowing bulls to perform their social ethogram and make transitions in a more confident way. Data obtained during this study, showed a slight advantage of perforated floor over the traditional fully slatted floor but these benfits were not comparable with those obtained with rubber mattress.

Regarding the fattening phase, younger animals were more likely to suffer of respiratory disease and hairless patches, probably caused by the stress of adaptation to the new rearing environment of the fattening unit and they appeared less confident to be approached by humans. At the end of the fattening cycle, bulls were more active and skin lesions and reduced cleanliness were more frequently observed.

A last study performed in Southern Alberta was focused on the importance of lameness in feedlot cattle. The average lameness prevalence in hospital pens was estimated as 37% and the rear limbs were the more frequently affected. Lame animals were more likely to spend time lying or standing still, reducing their feed and water intake and indirectly their growth performances. Lame animals had a significant drop in the inter observation weight gain as compared with cattle recovered in the sick pen for other health problems. The higher RBC, HTC and HGB values recorded in the blood of lame cattle were a consequence of a slight dehydration. Lameness treated cattle resulted to have lower values for white cell components (WBC, MONO and GRAN) than animals treated for respiratory diseases because the latter pathologies more frequently turn into a generalized disease that stimulate an immune response. Animal treated because respiratory disease and lameness and respiratory disease associated received more treatments in comparison with cattle affected by the other categories of disease. Animals affected by both respiratory disease and lameness were generally treated earlier than the other classes, while the occurrence of other pathologies like waterbelly, prolapses and bloated rumen was more frequent at a middle-late stage of the fattening, when cattle were on farm for more than 3 months.

In conclusion, aiming at improving the welfare of intensive fattened beef cattle, farmers should pay particular attention to pen floor. When using the deep litter, a proper management of the litter is required and it should imply the provision of an adequate amount of bedding material along with its frequent renewal. The use of dusty material should be avoided to lower the risk of respiratory problems. Cattle kept on slats are at higher risk of poor welfare and their discomfort might be reduced by covering the floor with rubber mattresses. Certainly, rubber flooring is not comparable to a well managed litter system or to the golden standard of the pasture grazing however it could entail the return of investment by lowering the risk of lameness and by promoting growth performance through an increased animal welfare level. Nevertheless, since discontinuous flooring allows to save labour managing manure, rubber covering could represents a compromise between beef cattle environmental requirements and the economic needs of intensive fattening units.

Observations carried out at the end of the fattening have shown that space allowance should be increased according to cattle growth in frame and weight. In heavier bulls, regardless of the type of pen floor, an adequate space allowance can be an effective strategy to lower agonistic interactions as well as the risk of disease occurrence, improving farm productivity.

As regard to the last study, it represents the first attempt to provide a general snapshot about lameness issue in Southern Alberta commercial feedlots system. Lameness in feedlots is probably underestimated by beef farmers and livestock industry, while public opinion is paying much more attention to this problem. However farmers' interest towards lameness reduction should be driven by the economic losses due to impaired growth performances, increased early culling and additional costs for medical treatment. The introduction of an action plan to reduce lameness as well as other risk factors for beef cattle welfare might be a way to promote the Canadian beef industry in future trade agreements with international partners such the European Union particularly addressed towards welfare friendly production system.

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