UNIVERSIDADE DE LISBOA

Faculdade de Medicina Veterinária

WELFARE INDICATORS IDENTIFICATION
IN PORTUGUESE DAIRY COWS FARMS

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DISSERTAÇÃO DE MESTRADO INTEGRADO EM MEDICINA VETERINÁRIA

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À minha mãe, Helena

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To my mother, my father, my sister and Diogo
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Welfare Indicators Identification in Portuguese Dairy Cows Farms

Catarina Krug

Abstract

The objective of this study was to determine the possibility of identifying dairy farms with poor welfare using a national cattle database. The welfare of dairy cattle was assessed using the Welfare Quality protocol on almost 2000 adult animals from 24 Portuguese dairy farms. More than 14 million records from national cattle database were analyzed to identify potential welfare indicators for dairy farms.

Within the 24 dairy farms, one was scored as 'enhanced', 18 were 'acceptable' and five were 'not classified', according to the Welfare Quality protocol. The main welfare problems identified were: presence of lesions and swellings mainly in the lower back legs and neck/back area; approximately 40% of moderate lameness; no pain management in disbudded calves; non-grazing production systems; insufficient or dirty drinkers; severe dirtiness of the udder and hindquarter; and high percentage of cows lying outside the stall.

Twelve potential welfare indicators were identified. Within these only two, proportion of on-farm deaths and female/male births ratio, were significantly different between farms with good welfare ('enhanced' and 'acceptable') and poor welfare ('not classified').

A model to detect farms with poor welfare was created with J48 classifier and it had 75.86% accuracy.

Key words: animal welfare, Welfare Quality, national cattle database, dairy cattle

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Identificação de Indicadores de Bem-estar Animal em Explorações de Bovinos Leiteiros em Portugal

Catarina Krug

Resumo

Este trabalho teve como propósito determinar a possibilidade de identificar vacarias de leite com baixos níveis de bem-estar através do Sistema Nacional de Identificação e Registo de Bovinos (SNIRB). Aplicou-se o protocolo *Welfare Quality* em cerca de 2000 animais adultos de 24 explorações portuguesas. Analisaram-se mais de 14 milhões de registos do SNIRB na tentativa de identificar potenciais indicadores de bem-estar nacionais.

Tendo como base os princípios do *Welfare Quality*, uma exploração foi classificada como tendo um nível de bem-estar "elevado", 18 obtiveram um nível de bem-estar "aceitável" e cinco não obtiveram os requisitos mínimos de bem-estar. Os principais problemas encontrados foram: presença de lesões e tumefações principalmente nas regiões do curvilhão e dorso; percentagem média de claudicação moderada por volta dos 40%; descorna sem controlo de dor; sistemas de produção sem pastoreio; bebedouros insuficientes ou sujos; elevado nível de sujidade no quarto traseiro e úbere; elevada percentagem de vacas deitadas fora do cubículo.

Identificaram-se doze potenciais indicadores de bem-estar nacionais. Apenas dois destes, "morte na exploração" e "rácio de nascimentos fêmea/macho", foram estatisticamente diferentes entre explorações com alto ("elevado" e "aceitável") e baixo (sem requisitos mínimos) níveis de bem-estar.

Usando o classificador J48 foi possível criar um modelo que detecta explorações com baixo nível de bem-estar e 75,86% das explorações foram correctamente classificadas.

Palavras-chave: bem-estar animal, Welfare Quality, base de dados nacional, bovinos de leite

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Acronyms

Ac	Acceptable score (20 to 49)
AD0	Percentage of cows that can be touched
AD050	Percentage of cows with avoidance distance between 0 and 50 cm
AD100	Percentage of cows with avoidance distance higher than 100 cm
AD50100	Percentage of cows with avoidance distance between 50 and 100 cm
AFC	Age at first calving
AWI	Animal Welfare Institute
B	Bad score (0 to 19)
Bad	Farms with ‘poor’ welfare
BCS	Body condition score
BSE	Bovine Spongiform Encephalopathy
C<272	Proportion of carcasses with less than 272 kg
C.272	Proportion of carcasses with less than 272 kg
CI<345	Proportion of calving intervals lower than the biological (345 days)
CI.345	Proportion of calving intervals lower than the biological (345 days)
CI>430	Proportion of calving intervals higher than 430 days
CI.430	Proportion of calving intervals higher than 430 days
Comfort	Comfort around resting
Cough	Mean coughing per cow per 15 minutes
DGAV	Portuguese official veterinary services (*Direcção Geral de Agricultura e Veterinária*)
DGSANCO	General Directorate for the Health and Consumer Protection
DHQ	Percentage of cows with dirty hindquarter
Diar	Percentage of cows with diarrhoea
Disea	Absence of disease
Dist	Percentage of cows with dystocia on the last 12 months before evaluation
DLL	Percentage of cows with dirty lower legs
Down	Percentage of downer cows on the last 12 months before evaluation
DP	Average displacements per cow per hour
DU	Percentage of cows with dirty udder
EC	European Commission
EFSA	European Food Safety Authority
EmgSl	Proportion of emergency slaughter
EU	European Union
FAWC	Farm Animal Welfare Council
FVO	Food and Veterinary Office
FM	Female/male births ratio
G	Good score (50-100)
Good	Farms with ‘good’ welfare
Hamp	Percentage of cows with hampered respiration
HB	Average head butts per cow per hour
Horn	Absence of pain induced by management procedures
HPHQ	Percentage of cows with hairless patch on the hindquarter
HPLBL	Percentage of cows with hairless patch on the lower back leg
HPLFL	Percentage of cows with hairless patch on the lower front leg
HPNB	Percentage of cows with hairless patch on the neck/back
HPU	Percentage of cows with hairless patch on the udder
Human	Good human-animal relationship
Hunger	Absence of prolonged hunger
Injur	Absence of injuries

LC	Percentage of cows that collide while lying
LD	Time to lie down
Lean	Percentage of lean cows
LHQ	Percentage of cows with lesion on the hindquarter
LLBL	Percentage of cows with lesion on the lower back leg
LLFL	Percentage of cows with lesion on the lower front leg
LNB	Percentage of cows with lesion on the neck/back
LO	Percentage of cows lying outside
LU	Percentage of cows with lesion on the udder
Mast	Percentage of cows with mastitis during the three months before evaluation
MCA	Multiple Correspondence Analysis
ModL	Percentage of cows with moderate lameness
Mort	Percentage of cows that died during the 12 months before evaluation
Mov	Ease of movement
Mt	Mortality rate (obtained by national database)
MtC	Calf mortality (until six months)
Nas	Percentage of cows with nasal discharge
NE	Dairy farms not evaluated
NIA	Percentage of cows without integument alterations
Ocu	Percentage of cows with ocular discharge
OFD	Proportion of on-farm deaths
Poor	Farms with ‘poor’ welfare
Prep	Proportion of partial carcass rejection
QBA	Qualitative Behaviour Assessment
SCC	Somatic Cell Count
SD	Standard deviation
SevL	Percentage of cows with severe lameness
SHQ	Percentage of cows with swelling on the hindquarter
SLBL	Percentage of cows with swelling on the lower back leg
SLFL	Percentage of cows with swelling on the lower front leg
SMOTE	Synthetic Minority Over-sampling Technique
SNB	Percentage of cows with swelling on the neck/back
SNIRB	National Database of Cattle Register and Identification (*Sistema Nacional de Identificação e Registo de Bovinos*)
Social	Expression of social behaviours
SRUC	Scotland Rural College
SU	Percentage of cows with swelling on the udder
Thirst	Absence of prolonged thirst
TLS	Total life span (months)
Trep	Proportion of total carcass rejection
VTC	Proportion of carcasses with fat class ‘very thin’ (class 1)
Vulv	Percentage of cows with vulvar discharge
WEKA	Waikato Environment for Knowledge Analysis
WHO	World Health Organisation
WQ	Welfare Quality®
WQclass	Welfare Quality® final classification
X30ppSl	Proportion of cows slaughtered at 30 days post partum
X60ppSl	Proportion of cows slaughtered at 60 days post partum
YMA	Percentage of cows with moderate integument alterations
YSA	Percentage of cows with severe integument alterations
30ppSl	Proportion of cows slaughtered at 30 days post partum
60ppSl	Proportion of cows slaughtered at 60 days post partum

Internship report

The present work was performed during the 6th year of Integrated Master in Veterinary Medicine (Faculty of Veterinary Medicine, Lisbon Technical University), under the supervision of George Stilwell and Telmo Nunes.

In the first month of internship (October 2012), I joined Professor George Stilwell's Large Animal Clinics practical classes (5th year). Among other clinical activities, I saw and performed disbudding of calves, functional and corrective hoof trimming, necropsies, exploratory laparotomies and treatment of downer cows.

From 6th November 2012 to 17th December 2012 I was in Scotland, Edinburgh, with the purpose of learning how to apply the Welfare Quality® (WQ) assessment protocol for dairy cows. I participated in a research project coordinated by Marie Haskell at the Scotland Rural College (SRUC, Roslin Institute). Part of that project was performed by Matt Turner and Mhairi Jack, that were applying the WQ protocol in Scotland's dairy farms, and I had the opportunity to join them for the evaluation on four of those farms. First I was in a SRUC's research farm to have an idea of what they did routinely and then, from the 19th to the 29th of November we went to farms in the south of Scotland, spending two days in each farm. In the remaining time I helped the project by inputting their collected data and by determining how to run the mathematical calculations necessary to determine the WQ protocol final scores.

The field study of the present work was conducted on 24 dairy farms in the centre and north of Portugal. In the beginning of January 2013 I presented my master project to 13 farmers that had their dairy farms in the centre of Portugal and during one month starting on January 17, I went to those 13 farms to apply the complete WQ protocol, spending an average of one day and a half on each farm. During the next two weeks I went to Vila do Conde, an area in the north of Portugal with many small and medium size dairy farms. Contact with farmers was made by Dr. António Manuel Ventura, member of *Cooperativa Agrícola de Vila do Conde*. The WQ protocol was performed in 11 farms, spending approximately one day in each. In five of these farms I was accompanied by five different veterinarians of the Portuguese official veterinary services (*Direcção Geral de Agricultura e Veterinária, DGAV*), from the Animal Welfare division, to give them some notions of how to perform the WQ protocol.

In March 2013 I calculated the final scores for each farm, according to the rules of the WQ protocol. From April to July I did the statistical analysis of potential welfare indicators of national level database validated through those field collected animal-based welfare indicators (WQ protocol).

Introduction

In the last 50 years, the main goal of dairy breeding was to increase milk production through genetic selection and management, therefore increasing farm profit and reducing cost for consumers. However, this one-sided selection for increased yield has brought, along with other factors, lower ability to reproduce, higher incidence of several production diseases, decreased longevity and modification of normal behaviour, which are indicative of a decrement of welfare of dairy cows (European Food Safety Authority [EFSA], 2009; Oltenacu & Broom, 2010).

Consumer demands are the most important drivers of change in breeding and production practices, and since the seventies that there has been a growing body of legislation on welfare within the European Union (EU; Broom, 2008). Therefore scientific and practical attention has been drawn to the improvement of welfare indicators and to more accurate measurements, with various on-farm welfare assessment protocols having been developed (Capdeville & Veissier, 2001; Sørensen et al., 2001; Main et al., 2007; Calamari & Bertoni, 2009). More recently, an EU project, the WQ protocol, has resulted in a more reliable on-farm monitoring system for cattle, pigs and poultry. Contrarily to the other protocols that were focused mainly in resource-based measures, the WQ protocol is focused on animal-based measures (Welfare Quality [WQ], 2009), or direct measures, which reflect the interaction between the animal and its environment (housing design and management; Whay et al., 2003; WQ, 2009). However, the WQ protocol is time-consuming and expensive and there are concerns about whether it can feasibly be implemented in practice (Knierim & Winckler, 2009). Therefore, it would be important to simplify this welfare evaluation into a fast but reliable method. One of the aims of this dissertation is to answer to that problem.

National herd databases contain a list of records that have become comprehensive since the Bovine Spongiform Encephalopathy (BSE) crisis, having the potential to be part of the future of welfare monitoring systems (Fraser, 2004; EFSA, 2012). In this study we aim to identify welfare indicators present on a national database that can help identify dairy herds with poor welfare. Similar studies have already been performed in Sweden by Sandgren et al. (2009) and in Denmark by Nyman et al. (2011). Another object of this study is to assess dairy cows' welfare situation in farms of the north and centre of Portugal and identify which are their main welfare problems by applying the modified WQ protocol.

CHAPTER I – Bibliographic review

1.1. Welfare

Broom states that "the welfare of an individual is its state as regards its attempts to cope with its environment" (Broom, 1996). To cope involves having control of mental and bodily stability and its prolonged failure will ultimately lead to fitness reduction (failure to grow, failure to reproduce or death; Broom, 2007). Other definitions of welfare include the subjective experience of the animal, its perception of the environment, while the World Health Organization (WHO) describes welfare as "a state of complete physical, mental and social wellbeing, and not merely the absence of disease or infirmity" (reviewed by EFSA, 2006).

According to Fraser (2003), there are three different views to define welfare:

1) the view that animals should be raised under conditions that promote good biological functioning in the sense of health, growth and reproduction;
2) the view that animals should be raised in ways that minimize suffering and promote contentment;
3) the view that animals should be allowed to lead relatively natural lives.

In addition, the Farm Animal Welfare Council (FAWC) has elaborated about the 'Five Freedoms' (Farm Animal Welfare Council [FAWC], 2009a):

1) free from thirst, hunger and inappropriate feed;
2) free from physical and physiological discomfort;
3) free from pain, injury and diseases;
4) free from fear, distress and chronic stress;
5) free from physical limitations to express normal behaviour.

These freedoms are a guide to those involved in farm animal husbandry as to their obligations towards the animals. Therefore, 'freedom' carries an implication of moral obligation towards an animal, and on the other hand, 'need' is a characteristic of the animal that has to be fulfilled to maintain its biological functioning, otherwise there will be poor animal welfare (Fraser & Broom, 1990). According to Noordhuizen and Metz (2005), the needs of an animal include: "feed and water intake, resting and lying, social interactions, health and animal safety".

Stress is defined as the "environmental effect on an individual which over-taxes its control systems and reduces its fitness or seems likely to do so" (reviewed by Broom, 2007). When there is stress*, there is poor welfare, however the opposite is not necessarily true, since stress

*It is important to refer, however, that this stress is actually called distress (chronic), because there is another kind of stress (eustress) that is beneficial for the animal and is not associated with poor welfare.

is related to failure to cope and poor welfare is related to both difficulty in coping and failure to cope (Broom, 2007).

1.2. Welfare indicators

EFSA (2006) has divided welfare indicators in four categories: pathological indicators, physiological indicators, behavioural indicators and productive indicators.

Pathological indicators

According to Broom (2006), animals with disease "have more difficulty in coping with its environment and some harmful effect on its functioning, and so there will be worse welfare". Moreover, when disease is associated with pain or malaise, welfare is even poorer. The opposite may also happen, in which reduced welfare can increase disease susceptibility by causing immune-suppression (reviewed by Broom, 2006).

Examples of pathological indicators include those related to hoof, gastro-enteric, respiratory and metabolic diseases. Body lesions related to management are also included in this class, as is mortality and morbidity, that are a clear evidence of reduction in animal health and so considered pathological indicators too (EFSA, 2006).

Physiological indicators

Measuring hypothalamic-pituitary-adrenal axis activity by measurement of glucocorticoid hormones (cortisol, corticosterone) in blood plasma is a physiological indicator that is commonly used, mostly during short-term management practices. Frequent adrenal activity may lead to immune-suppression, which can also be used as an indicator of welfare (Fraser & Broom, 1990). These indicators have to be interpreted with caution, since levels can rise in situations other than stress (reviewed by Dawkins, 2004).

Behavioural indicators

Using behaviour to assess animal welfare is advantageous since it is non-invasive and normally it does not disturb the animal (Dawkins, 2004).

Abnormal behaviour such as stereotypies, self-mutilation, redirected behaviours and excessively aggressive behaviour can be an indication that the welfare is poor (Broom & Fraser, 2007). Inability to carry out normal behaviour (e.g. locomotion) and the occurrence of behavioural signs of pain such as rigid posture, grunting or grinding of teeth can also be used as indicators of poor welfare (Fraser & Broom, 1990). Signs of fear are another indicator and

they are commonly used to evaluate human-animal relationship (Rousing et al., 2000). Other examples are comfort behaviour (e.g. time resting) and feeding behaviour (EFSA, 2006).
Behaviour also allows to assess what animals want by using choice and preference tests (e.g. evaluating their spatial distribution), or by looking for behaviours that are accompanied with circumstances that they want or want to get away from (e.g. vocalisations made by piglets when they want to eat; Dawkins, 2004).

Productive indicators

According to Broom, "the best measure of what is detrimental is reduced fitness of the individual" (reviewed by Fraser & Broom, 1990). Fitness can be calculated by measuring age at first calving, calving interval, survivorship from birth to first calving, survivorship of adults between consecutive breedings and number of female offspring per female breeding attempt. These indicators can be measured directly or they might be strongly suggested by poor growth, inadequate reproductive functioning, poor lactation or maternal behaviour, high levels of injury or increased disease susceptibility (reviewed by Fraser & Broom, 1990).
However, according to Dawkins, production parameters are not relevant to welfare, since most of them are taken at farm level and the overall production of the farm can be acceptable even if some animals are in poor conditions (reviewed by Botreau et al., 2007).

1.2.1. Welfare Evaluation – Welfare Quality® protocol

As stated by Fraser (1995), welfare is a multidimensional concept, as several measures are needed to make an overall assessment of welfare. That is the reason why the WQ protocol is based on the use of four principles – good feeding, good housing, good health and appropriate behaviour – which are linked to 12 criteria (Table 1), and none of the single measures is able to cover all the dimensions of welfare (Botreau et al., 2007). The objectives of these principles have some similarities to the 'Five Freedoms', and they are generally in agreement with 2009 EFSA scientific opinion (EFSA, 2012).

Principles	**Welfare Criteria**	**Indicators**
Good feeding	Absence of prolonged hunger	Percentage of very lean cows
	Absence of prolonged thirst	Water provision, cleanliness and functioning of water points
Good housing	Comfort around resting	Time needed to lie down, percentage of cows colliding with equipment when lying, percentage of cows lying completely/partly outside the cubicle, percentage of cows with dirty udder, dirty flank/upper legs and dirty lower back legs
	Thermal comfort	As yet, no indicator is developed
	Ease of movement	Presence of tethering
Good health	Absence of injuries	Percentage of cows moderately and severely lame, percentage of cows with severe integument alterations (swellings and lesions) and with mild integument alterations (hairless patches)
	Absence of disease	Mean number of coughs per cow per hour, percentage of cows with nasal, ocular and vulvar discharges, diarrhoea, hampered respiration, SCC>400,000 cells/mL, percentage of on-farm mortality, dystocia and downer cows
	Absence of pain induced by management procedures	Disbudding/dehorning and tail docking (methods and use of anaesthetics and analgesics during procedure)
Appropriate behaviour	Expression of social behaviours	Mean number of head butts and displacements per cow per hour
	Expression of other behaviours	Number of days per year with access to pasture
	Good human-animal relationship	Percentage of cows that can be approached 0 to 10cm, >10 to 50cm, >50 to 100cm, and >100cm
	Positive emotional state	Scores of 20 terms of the Qualitative Behaviour Assessment (Annex 2)

Table 1 – Welfare principles, criteria and indicators of Welfare Quality® protocol for dairy cattle (WQ, 2009)

1.2.1.1. Good feeding

a) Absence of prolonged hunger (Body condition score)

Body condition score (BCS) provides a subjective estimate of the amount of fat below some specific areas of the body (tail head, pin bones, hip area, lumbar vertebrae; Hulsen, 2006). Either high or low BCS at calving can reverberate into less milk production, impaired reproduction and reduced immune function (Hulsen, 2006; Roche et al., 2009). Obesity may increase the risk of metabolic disorders, while thinness may increase the risk of cold discomfort in cold environments (Roche et al., 2009).

There is a variety of methods to evaluate the BCS. The one described by Fergusson et al. (1994), using a five point scale, seems to be the most used. The WQ protocol uses a three point scale, in which zero corresponds to a regular BCS, one to very lean cows and two to very fat cows.

b) Absence of prolonged thirst (Water supply)

Cows that are lactating, over-heated or sick, have higher demands for water than other cows, therefore, they will become dehydrated earlier in the absence of water. Cows can drink between 14 and 171 litres per day, varying with season, production level, exercise and water and mineral content of the feed (Meyer et al., 2004). If they do not drink enough, dry matter intake decreases and, as a result, production will be affected negatively.

Given a choice, cows prefer the cleanest and freshest water, therefore the drinkers should be cleaned regularly to maintain the cleanliness of water and to avoid excessive microbial growth (particularly during warm weather; Hulsen, 2006).

To evaluate the criterion 'absence of prolonged thirst', the WQ protocol presents three indicators – number of animals per drinker, length of water troughs and water flow – which have been proved to be associated with cows' water intake (Filho et al., 2004; Teixeira et al., 2006).

1.2.1.2.Good housing

a) Comfort around resting (Cleanliness, Lying behaviour)

The needs of dairy cows include resting and sleeping. When these needs are impaired, cows present reduced rumination, increased risk for lameness and alterations or injuries regarding hair, skin and joints (Winckler, 2008).

Cleanliness

The quantity of dirt on cows gives an idea of the cleanliness of the farm. It depends on the cleanliness and dryness of the resting area, type of floor and frequency of scraping, presence of brushes and milking procedure (Hulsen, 2006; Andreasen & Forkman, 2012).

Dirty skin and hair may induce itching, diminish thermoregulatory properties and antimicrobial defense and can cause dermatitis (Winckler et al., 2003). Dirtiness and mastitis have been associated (Reneau et al., 2005; Sant'Anna & da Costa, 2011). According to Reneau et al. (2005) a 1-point change in herd average cleanliness score (composite udder-hind limbs score on a one [clean] to five [dirty] scale) resulted in a 50.000 cells/ml change in bulk tank somatic cell count. Cows that are kept clean have also a lower risk for hoof disease (reviewed by EFSA, 2009).

Lying behaviour

Increased laying down time, can be an indication of painful conditions of the hoof, vertebral column and udder (Fregonesi & Leaver, 2002), or it can be a sign of dirtiness of the cubicles (e.g. covered with manure and slippery). Difficulties in lying down can lead to injuries, discomfort and reduced resting (Winckler et al., 2003).

A study of Popescu et al. (2013) has shown a relation between the duration of the lying down movements and the percentage of lame cows, cows with mastitis, and with cows with at least one lesion. Another study correlated positively the time to lie down and dirtiness of the flank/hindquarter and udder (DeVries et al., 2012).

Another welfare problem that can be associated with the lying movement of the dairy cow is its hitting against the cubicles. This can happen in the presence of lameness, when the animal protects the affected limb avoiding putting weight on it (Popescu et al., 2013).

When the cubicles do not have sufficient dimensions, animals can lay partly outside the resting area, becoming dirtier and allowing the occurrence of skin and limb lesions and infections (Mattiello et al., 2009).

b) Ease of movement (Tethering)

Tie-stall housing is still used extensively worldwide despite of the welfare concerns regarding the restriction of free movement and limitation of cows' self-maintenance and social behaviour often for long periods (EFSA, 2009; Popescu et al., 2013).

In a study of Araújo et al. (2007) performed in 1,882 northern Portuguese farms, milking cows were tethered (tie-stalls) in 24.2% of the farms, 22.8% used loose housing systems while the majority used the free-stall system (52.4%).

1.2.1.3. Good health

a) Absence of injuries (Lameness, Integument alterations)

Lameness

Lameness can be defined as an abnormal gait or impaired movement and it can be caused by any painful, mechanical or neurological problem (Fraser & Broom, 1990). Claw disorders cause about 90% of lameness in dairy cattle (reviewed by Sogstad et al., 2007), which is associated with the limited capacity that the claw tissue has to resist to mechanical stress without being damaged (Frank et al., 2006). The weight bearing capacity of claws is, among others, determined by its size and surface profile and by the characteristic of the floor surface (van der Tol et al., 2002; 2004). The use of concrete floors (Somers et al., 2003), zero grazing (Haskell et al., 2006) and uncomfortable stalls (Vokey et al., 2001) are important risk factors affecting lameness. The frequency of milking and the distance from pens to the milking parlour are also relevant (Andreasen & Forkman, 2012). Large sized udders have been related to the development of lameness, by causing splay-legged walk and uneven foot wear (Boelling & Pollott, 1998).

Lameness alters normal activity of the animal, prolonging the time spent laying down (Chapinal et al., 2009; Chapinal et al., 2010; Langford et al., 2011) while reducing sexual activity and feed intake and increasing live weight loss (reviewed by Sogstad et al., 2007). It affects milk production, reducing yields between 1 and 20% (Blowey, 1993), and it also affects reproductive performance (Garbarino et al., 2004), contributing to earlier culling (Sogstad et al., 2007). The combination of these factors plus the costs for treatment of lame cows, cause negative economic consequences to the farmer (Kossaibati & Esslemont, 1997).

Correctly carried functional hoof trimming once or twice a year is a way of preventing lameness in dairy cows (Espejo & Endres, 2007). Foot bathing is also useful (Laven & Hunt, 2002).

Locomotion scoring systems normally range from one to five. A well-known example is the system developed by Sprecher et al. (1997). Similarly to what happens with BCS, the WQ protocol uses a scale from zero to two to evaluate lameness, and it does not include the extent of back arch, oppositely to other scoring systems.

Integument alterations

Integument alterations are scored in terms of severity in hairless patches (less severe), scabs, wounds and swellings (most severe; Lombard et al., 2010). They frequently result from collisions against the cubicles, pressure against feed trails while eating or from contact with hard floors. The most affected body areas are normally the carpal, fetlock, hock and stifle joint, neck/wither, shoulderblade, dewlap, hip and ischial tuberosity (reviewed by Winckler et al., 2003).

The stalls' surface and bedding quality have been shown to be important risk factors to the development of integument alterations on the hocks. When compared to rubber mats and mattresses, sand was found to be the surface that gives lower risk of causing those alterations (Andreasen & Forkman, 2012). Potterson et al. (2011) concluded that hair loss and ulceration on the hocks had five risk factors in common (locomotion score, number of days of winter housing, mean milk yield, freestall base material and herd size), but, because there were some unique risk factors for each, they concluded that ulceration does not always have to be a direct extension of hair loss. Swelling seemed to have a different aetiology than hair loss and ulceration, since only one risk factor (stall bedding material), in a total of 12, was common to other lesion (hair loss). Locomotion score was presented as a risk factor which can be associated with the fact that lame cows lie for longer periods of time, being more exposed to the stall surface, therefore allowing the formation of those integument alterations (Potterton et al., 2011). But the opposite case is also possible, where the association of abrasions and dirty/wet stalls may result in infection of the skin on the hock and then extending progressively to the subcutaneous layer (stiff gait) and to the joint, provoking a severe lameness on the animal (Hulsen, 2006).

b) Absence of diseases (Clinical examination, herd records)

Hampered respiration, cough and nasal discharge

Coughing and abnormal nasal discharge are typical indicators of respiratory disease. Tachypnea in dairy cattle is normally associated with heat stress (Radostitis et al., 2007).

Infectious diseases of the respiratory tract are multifactorial. There are some predisposing causes such as inclement weather and poorly ventilated housing, each of which can weaken the immune system of the animal. Consequently, the prevention focuses on minimizing exposure to inciting agents, maximizing innate resistance with a good nutrition, housing and animal welfare and administering effective vaccines (Radostitis et al., 2007).

Within the commonest infectious respiratory diseases, there is the bovine respiratory syndrome, infectious bovine rhinotracheitis, bovine respiratory syncytial virus and bovine parainfluenza 3.

Ocular discharge

Exposure of the eyes to dust or poorly ventilated environments can predispose for the occurrence of ocular discharge. Infectious bovine keratoconjunctivitis, infectious bovine rhinotracheitis and malignant catarrhal fever are some possible aetiologies. Foreign bodies, normally of plant origin, are also a possible cause (Riis, 2008).

Mastitis (based on questionnaire)

Mastitis is an inflammation of the mammary gland and it can be presented as clinical or subclinical. Clinical mastitis is associated with abnormalities in secretion, size, consistency and temperature of the mammary gland. There might also be systemic signs (Radostitis et al., 2007). Subclinical mastitis is detected only by diagnostic tests such as the SCC or the Californian Mastitis Test, since it does not exhibit clinical signs (Busato et al., 2000). When SCC is above 200,000 cells/mL, it indicates subclinical mastitis (Dohoo & Leslie, 1991), while a mean SCC of 68,000 cells/mL indicates healthy quarters (Pyörälä, 2003).

Mastitis leads to a substantial reduction of the milk yield and increased costs of production, resulting in economic loss for producers (Radostitis et al., 2007).

The major risk factors for mastitis are: story of mastitis in the preceding lactation, which gives twice of susceptibility to the development of clinical mastitis in the current lactation (Firat, 1993); poor management of housing and bedding that predispose infection with environmental pathogens; and poor milking practices (Radostitis et al., 2007). Therefore to avoid the development of the disease, it is important to optimize the hygienic procedures of the environment, to have a correct functioning of the milking machine, dipping all teats after each milking and monitoring of udder health status. Also, since the dry period is the time of greatest risk of infection (Green et al., 2002), antimicrobial therapy and prevention of new infections by applying an internal teat sealant at drying, are efficacious measures. Chronically infected cows should be culled (Radostitis et al., 2007).

Diarrhoea

Diarrhoea might have infectious, parasitical, toxic, nutritional or metabolic origins. Within the most common infectious diseases that can cause diarrhoea in cattle, there are salmonellosis, winter dysentery, Johne's disease and Bovine Virus Diarrhoea (Radostitis et al., 2007). Nevertheless, subclinical ruminal acidosis is a more important cause for diarrhoea in adult cattle than infectious diseases. It is a common syndrome in lactating cows, being mainly related to consumption of an excess of rapidly fermentable concentrates (Fubini & Divers, 2008) and it may lead to several sequelae, such as laminitis (with subsequent lameness), liver abscesses or pneumonia (Kleen et al., 2003), which have a significant impact on animal welfare.

Vulvar discharge

Presence of a purulent vaginal discharge is normally indication of clinical metritis or endometritis, however a rectal palpation should be done to make sure that the pus comes from the uterus and not from the cervix or vagina, that can also produce abnormal discharges when inflamed (Manspeaker, 2010). There are other methods for a more reliable diagnosis (e.g. biopsy, ultrassonography), however, clinical examination is inexpensive and quick, thus being the most used on field (Sheldon et al., 2006).

Metritis is an inflammation of uterus caused by an influx of pathogens during calving or in the early postcalving. Less frequently, microorganisms can also enter the uterus from a systemic or from a venereal route (Manspeaker, 2010). *Arcanobacterium pyogenes*, *Bacteroides* spp., *Fusobacterium necrophorum* are the predominant microorganisms present in cows with post-partum metritis. These are also present in cows with retained placenta, which is a major risk factor for the occurrence of postpartum septic metritis, with cows with retained placenta having 25 times more chance of developing metritis (Radostitis et al., 2007). Other factors associated with metritis are large herds, dystocias, twins and overconditioning or underconditioning of cows (Kaneene & Miller, 1995).

According to Chapwanya (2008) metritis can occur on the first 21 days postcalving, after which endometritis might evolve. Unresolved endometritis would then progress to pyometra 43 days or more after calving. Prognosis is highly related to the immunological status of the cow. Only 20% of cows with metritis fail to eliminate uterine pathogens thus developing endometritis. This can lead to long-term effects such as subfertility (Dobson et al., 2007; Mee, 2007).

Prevention of this disease relies on avoiding the risk factors, such as retained placenta. This can be done with a proper nutrition during dry off and a normal calving process under hygienic circumstances **(**Opsomer & de Kruif, 2009).

Dystocia (based on questionnaire)

Dystocia is defined as prolonged or difficult parturition normally requiring assistance. It increases the chances of retained placenta, uterine disease, mastitis and hypocalcaemia (reviewed by Mee, 2008) and the incidence of cow and calf mortality (McClintock et al., 2005).

Primiparous cows have higher probability of developing dystocia than multiparous cows (Meyer et al., 2001; McClintock et al., 2005), mainly due to feto-maternal disproportion, immaturity (young heifers) and over fatness (older heifers; reviewed by Mee et al., 2011). Birthweight is also a risk factor for dystocia (Johanson & Berger, 2003).

Control is made through genetic selection programmes, specific sire choice, heifer growth, periparturient management and adequate calving assistance (Mee, 2008). Research has shown that any calving assistance is associated with higher risks of stillbirth (Bicalho et al., 2007) and reduced fertility (Buckley et al., 2003), thus being so important to avoid unnecessary calving assistance.

Downer cow syndrome (based on questionnaire)

Downer cow is a situation where an animal in sternal recumbency is unable to rise to a standing position. This is due to musculoskeletal and nerve injuries associated with prolonged recumbency on a hard surface (Radostitis et al., 2007). There are a variety of aetiologies: systemic causes, such as hypocalcaemia (milk fever), hypophosphatemia, fatty liver syndrome and toxaemia by mastitis, metritis or peritonitis; and local causes such as periparturient paresis. To avoid these, prevention through nutrition, management and premises are crucial, especially on periparturient animals (Stilwell, 2009a). With milk fever as a major cause of downer cow syndrome, prepartum diets with chloride and sulfur in excess to sodium and potassium, administration of calcium gel and administration of vitamin D in the peripartum are some measures that could diminish the chances of developing downer cow syndrome. Also, placing the pregnant animal in a comfortable well-bedded box stall prior and after calving is an important measure (Radostitis et al., 2007).

A high percentage of downer cows die or is euthanized. Those that survive can manifest some sequelae, such as higher somatic cell counts, udder lesions, lower yield, fertility problems, metritis and chronic musculoskeletal injuries (Stilwell, 2009a). Research has shown that downer cows have a probability of 35% of being culled in the first 150 days of lactation (Houe et al., 2001). Besides the obvious welfare problems associated, downer cow syndrome results in economic losses to the farmer related to lower production and costs for treatment and culling.

Mortality (based on questionnaire)

According to Thomsen and Houe (2006), high rates of mortality cause financial losses and are an important welfare problem. This issue would be associated with “suffering before death or euthanasia”.

In assessing animal welfare, measures of mortality are more useful if the cause is known, besides, it can help dairy farmers to prevent future deaths. However, it is not part of most farmer’s routine to try to understand the cause of death by performing a necropsy, probably because it is seen as impractical and time consuming (McConnel et al., 2010).

Previous research has recognized increased proportion of purchased cows, greater rates of production diseases, early lactation, longer calving intervals, larger herd sizes and no pasture-grazing as risk factors for mortality (Thomsen et al., 2006; 2007; Miller et al., 2008; Raboisson et al., 2011). Also, some studies have associated milk production with mortality rate, however these results have been inconsistent, with some observing a positive relationship (McConnel et al., 2008; Miller et al., 2008), and others founding a negative relationship between both variables (Smith et al., 2000; Thomsen et al., 2006; Alvasen et al., 2012). On the other hand, Dechow and Goodling (2008) have concluded that herds with high mortality had younger cows (1^{st} and 2^{nd} lactation) producing more milk and older cows (4^{th} lactation and greater) producing less milk than herds with low mortality.

c) Absence of pain induced by management procedures (Dehorning, tail docking)

Dehorning (based on questionnaire)

The disbudding of calves is commonly performed, to avoid the potential injuries on both animals and farmers by horned cows.

Research has shown that dehorning causes pain to calves, being important to administer a combination of sedative, local anaesthetic and nonsteroidal anti-inflammatory drug to reduce it (von Keyserlingk et al., 2009). Disbudding can be performed by amputation (e.g. scoop, wire, saw), thermocauterization (hor-iron) or applying caustic paste. According to Stilwell et al. (2009), the use of local anaesthesia associated with nonsteroidal anti-inflammatory provides a successful reduction in pain when using the caustic paste to disbud. With this method, pain seems to be easier to control than using hot-iron disbudding associated with sedative and anaesthetic (von Keyserlingk et al., 2009). On the other hand, the Animal Welfare Institute (2011) states that hot-iron disbudding correctly performed is the best of the methods. Caustic paste is usually performed between two and four weeks of age, while the thermocauterization is done at four to eight weeks (Stilwell, 2009b).

Dehorning adult cattle is associated with high risks of sinusitis (Ward & Rebhun, 1992), therefore it should be performed on cool and dry days to minimize the risk of infection (reviewed by EFSA, 2009). It is usually done with wire-saw, saws, scoop or guillotine clippers. However, when it is necessary, tipping the horns should be chosen over gouge dehorning. In the future, the goal is to select and breed polled cattle to eliminate animal suffering due to dehorning (Animal Welfare Institute, 2011).

Tail docking (based on questionnaire)

Tail docking is limited in the EU. In other countries (e.g. USA), tail docking is largely done because it is believed to increase cow cleanliness and therefore to reduce the risk of mastitis (Tucker et al., 2001). It is also done to reduce urine and faeces scattering in the milking parlour soiling the stockperson. In contrast, many studies have proved that tail docking does not bring advantages to cows' cleanliness (Tucker et al., 2001; Schreiner & Ruegg, 2002; Stull et al., 2002; Lombard et al., 2010), in fact, tail docking affects negatively the welfare of cows by preventing them to get rid of flies (von Keyserlingk et al., 2009), which can result in lower milk yield (Jonsson & Mayer, 1999). Moreover, tail docking can be associated with the formation of neuromas, resulting in chronic pain (Stull et al., 2002; Eicher et al., 2006).

To avoid dirty tails, an alternative to tail-docking is switch trimming (Stull et al., 2002), along with improving nutrition and health of dairy cows (Hulsen, 2006).

1.2.1.4. Appropriate behaviour

a) Expression of social behaviours (Frequency of agonistic behaviours)

According to Menke et al. (1999), in horned cows the frequency of agonistic behaviours is positively correlated with the occurrence of skin injuries.

Competitive goals like resting sites, food, water and sexual partners induce agonistic behaviours between herdmates, being important a well-balanced herd density. The presence of females in oestrus increases the level of agonistic interactions (Albright & Arave, 1997), as it does the introduction of new elements in the herd (von Keyserlingk et al., 2008). When herds are too large, animals have difficulty in recognizing each other and that also results in a negative impact on their type of interactions (reviewed by EFSA, 2009).

The presence of manger divisions seems to allow submissive cows to eat longer (reviewed by Albright & Arave, 1997). Similarly, DeVries and von Keyserlingk (2006) concluded that feed stalls combined with a decreased herd density reduced competition at the feed rail, as it did the increment of the feed bunk space from 0.64 to 0.92 m/cow.

b) Expression of other behaviours (Pasture)

In the north and centre of Portugal, adult dairy cows are rarely allowed to access pasture. But on the south and in the Azores archipelago the scenario is quite different. In some European countries (e.g. Sweden, UK) legislation obligates to a minimum time at pasture.

Research shows that cows have a partial preference for pasture at night, choosing indoor housing during the day, to eat and escape from harsh climatic conditions (Falk et al., 2012).

Some studies show that cows that have access to pasture have less hoof problems when comparing to zero-grazing circumstances (Haskell et al., 2006; Hernandez-Mendo et al., 2007). There are other diseases that were shown to be at higher incidence on cows without access to pasture, such as mastitis, metritis, dystocia and downer syndrome. Also, culling rates are higher in zero-grazing cows (Bruun et al., 2002; Washburn et al., 2002; White et al., 2002; Green et al., 2008).

On pasture, cattle have access to more space, better air quality, they show a bigger range of normal behaviours, and less agonistic interactions (Hemsworth et al., 1995; Falk et al., 2012). Besides, their direct access to natural light lets them get vitamin D through the radiation of the skin, which is the principal regulator of calcium homeostasis. But access to pasture also exposes cattle to inclement weather, increased parasite load, toxic plants and inadequate energy intake. Some studies reported that cows that have access to pasture produce less milk (Washburn et al., 2002; White et al., 2002; Hernandez-Mendo et al., 2007).

c) Positive emotional state (Qualitative behaviour assessment [QBA])

The ability of recognizing that the welfare is good by positive evidence is extremely limited (Fraser & Broom, 1990). In 1980, Marian Dawkins published a book in which she pointed out the importance of animal’s feelings on welfare, and since then, there has been a growing interest in exploring this theme (reviewed by Duncan, 2005). According to Fraser and Broom (1990), the best way of finding out what is good for animals is to observe their preferences and what costs the individual is willing to incur to express the preference. The preference test is the starting point for an investigation into how the animal feels, however, it has various problems associated, which have been discussed in detail (Duncan, 1992). Other information about feelings can be obtained indirectly from studies of physiological and behavioural responses of animals (Broom, 2007).

Emotions are adaptive programs that are intended to direct other physiological programs or to solve adaptative problems faced by species over time (Boissy et al., 2007). In other words, feelings are used to maximize fitness, often helping animals with complex nervous systems (vertebrates, cephalopods) to cope with its environment (Broom, 2007).

“Emotions are determined on the basis of (…) the novelty of the event, its intrinsic pleasantness, its goal significance, the coping potential of the individual and the relevance to social norms” (reviewed by Boissy et al., 2007). Negative emotional states are often called ‘suffering’, including states of pain, fear, frustration, deprivation or boredom (Mason & Mendl, 1993). Positive emotional states are called ‘pleasure’ (Duncan, 2002). Play behaviours, affiliative behaviours (e.g. allo-grooming), and some vocalizations are possible indicators of positive affective states in animals (Boissy et al., 2007).

QBA methods were developed to characterize global expressive affects, in which ‘relaxed’, ‘friendly’, ‘affectionate’, ‘playful’ and ‘social’ have been associated with positive states (Wemelsfelder & Lawrence, 2001).

There has been some reluctance in accepting this sort of behavioural evaluation, because behavioural science traditionally distrusts expressive terminologies, fearing these may be based on anthropomorphic judgments of uncertain validity (Wemelsfelder & Lawrence, 2001). However, QBA based on a free choice profiling methodology has shown high levels of inter- and intra-observer reliability, and the results obtained suggest that it may be a reliable method for the on-farm assessment of social interactions in dairy cattle (Rousing & Wemelsfelder, 2006).

d) Good human-animal relationship (Avoidance distance)

To assess animals' fear of people, there are: 'handling measures', that assess the animals' response to being handled; 'rating scales', that consist in a subjective rating of the animal; and 'distance measures', that are divided in two types, 'approach' distance (where the animal approaches a person that is immobile) and 'flight' distance (which is the distance that the animal allows a person to approach before escaping; Passillé & Rushen, 2005). The flight/avoidance distance test is the one that has been selected by the WQ Protocol to evaluate the human-animal relationship.

The results of the avoidance distance test can be affected by some variables such as the clothing worn (reviewed by Albright & Arave, 1997; Munksgaard et al., 1999; Passillé & Rushen, 2005) or the location of the test, reducing its validity and reliability. Furthermore, one study has shown that cattle do respond differently to familiar and unfamiliar people (reviewed by Rushen et al., 1999), while others found that the responses to both familiar and unfamiliar people were similar (Krohn et al., 2001; Breuer et al., 2003). Thus, according to Passilé and Rushen (2005) it should not be assumed that responses of cattle to an unfamiliar person are a reflection of their responses to their caretakers. However, some studies concluded that the avoidance distance correlated significantly with the milker's behaviour, supporting the validity of this assessment (Waiblinger et al., 2002; Waiblinger & Menke, 2003; Waiblinger et al., 2003). The inter-observer reliability of the avoidance test was high according to Rousing and Waiblinger (2004). Waiblinger and Menke (2003) showed that smaller sample sizes decrease the validity and reliability of this measure.

Aversive handling causes stress and it is associated with reduced reproductive performance (Breuer et al., 2003). In some studies, aversive handling of animals by stockpeople was negatively associated with milk yield (Hemsworth et al., 2002; Waiblinger et al., 2002), as well as flinch, step and kick responses by the cow during milking (Breuer et al., 2000; Bertenshaw et al., 2008). On the other hand, cows less fearful and more friendly to people are less likely to kick the milker(s), and produce more milk (reviewed by Albright and Arave, 1997). A recent study found that positive handling by stockpeople during milking was associated with lower SCC and with lower prevalence of mastitis quarters (Ivemeyer et al., 2011).

The way farmers handle cattle is likely to be a reflection of long-held beliefs about how animals need to be handled and attitudes towards animals in general (Hemsworth, 2003). Research has shown that aversive handling can result in a generalized fear of people, but this can be reverted by positive handling (Mench, 2004). The best occasions to make cows associate stockpeople with pleasant experiences will occur during handling before calving, at calving, in the collecting yard and during milking. Feed rewards, patting the cow, speaking in a pleasant tone of voice and approaching the cow are some measures that can be taken by the stockpeople to reinforce their relationship with the animal (reviewed by Albright and Arave, 1997). The conclusions of Schmied et al. (2008) were consistent with this, showing that cows stroked in specific body regions were more willing to approach human and had a lower avoidance distance.

1.2.2. European and Portuguese legislation for welfare in dairy cattle

In the EU Commission, the scientific committee on Animal Health and Animal Welfare, now part of EFSA is responsible for reviewing scientific evidence on any aspects that might affect animal welfare and provides recommendations to the General Directorate for the Health and Consumer Protection (DGSANCO) on how to protect animals. After that, DGSANCO may decide to draft a directive that becomes a Council Directive after receiving approval from the Council of Ministers of the EU. Summarily, the trends of EU directives for rearing of farm animals are (Veissier et al., 2008):

1) To increase space allowance per animal;
2) To permit interactions between animals, and hence to encourage group housing;
3) To give more freedom of movement;
4) To provide animals with an enriched environment;
5) To feed animals a regimen consistent with their physiological and behavioural needs;
6) To limit painful intervention.

EU directives have been translated into Portuguese regulations (e.g. decrees) so that they could be applied to Portuguese farms. One example is the decree number 64/2000 from April 22 (*Decreto-Lei n.º 64/2000 de 22 de Abril*) which is the result of the approval of the Directive 98/58/CE (*Directiva 98/58/CE de 20 de Julho*) relative to the Protection of Animals kept for Farming Purposes. To guarantee the fulfilment of this decree, the competent authorities, *DGAV*, make an annual inspection of the registered farms.

On January 2012, the European Commission released a communication on the "EU strategy for the protection and welfare of animals" from 2012 to 2015 (European Commission [EC], 2012). To answer the main issues that compromised animal welfare in the EU, some specific targets were set (EC, 2012):

1) To improve enforcement of the EU legislation in a consistent approach across the Member States;
2) To provide for open and fair competition for EU business operators that implement or go beyond EU requirements;
3) To improve knowledge and awareness of EU business operators regarding animal welfare;
4) To improve the coherence of animal welfare across animal species.

To achieve these goals, four routes have been identified (EC, 2012):

1) Strengthening Member States’ compliance;
2) Benchmarking voluntary schemes;
3) Establishing a European network or reference centre;
4) Streamlining requirements for competence and using animal welfare indicators.

Strengthening Member States’ compliance would be especially useful in reinforcing the EU legislation by allowing exchange of good practices between the different competent authorities. Route 4 would be important on this matter too, by creating the requirement for a minimum level of competence for animal handling (a simplified version of the WQ protocol could be used; EC, 2012).

The overall impact of benchmarking voluntary schemes (route 2) on open and fair competition for EU business operators is expected to be very positive since it would favour the existence of high and basic welfare standards allowing producers to make improvements depending on the business opportunities, and being a tool to the development of their own certification schemes. Establishing a European network or reference centre would be a resource for investigation on animal welfare and it could support the development of certification schemes increasing competitiveness and fairness between business operators (EC, 2012).

Route 3 would also have good impact on improving knowledge of EU business operators, but it only reaches those people that want to be trained. Opposing to this, option 4, streamlining requirements for competence and using animal welfare indicators, would affect everybody and therefore its impact at improving knowledge of business operators on animal welfare would be very positive, moreover, operators would understand animals better and so they would act more responsibly towards them (EC, 2012).

According to EFSA (2012), national databases can provide animal-based measures at the national level. Benchmarking of these measures would give a quick feedback to policy makers on the application of legislation or other initiatives to improve animal welfare.

1.2.3. National cattle database's potential welfare indicators

Possible welfare indicators were identified through a bibliographic review. Then it was important to define which databases could be assessed. The possibilities included records from individual farms, dairy cooperatives, animal health laboratories or national cattle databases. These contain a large records list that have high potential for animal welfare. In Portugal, three information systems were identified, the system of on-farm fallen stock collection (*Sistema de Recolha de Cadáveres de Animais Mortos na Exploração [SIRCA]*) which has data already included on the National Database of Cattle Register and Identification (*Sistema Nacional de Identificação e Registo de Bovinos [SNIRB]*) and there is also another database that has data relative to the ungulates' meat inspection (*SIPACE*). This one could be useful if causes of rejection were fully described for each slaughtered animal, however records are relative to animal batches. As a result, *SNIRB* was the elected database. It has records of fertility, mortality, movements and carcass characteristics. Some of these will be discussed in this dissertation in terms of welfare. Despite this selection of indicators, other records could also be useful if they were available, such as: treatment records during lifetime that could give an idea of the diseases suffered; specific culling reasons for each cow; rejection causes for each slaughtered cow.

1.2.3.1.Fertility

There are two possible relationships between welfare and fertility:

1) Reduced welfare can be the cause of reproductive disorders, causing lack of oestrus, embryonic loss or early abortion due to stress experienced around calving and in early lactation (EFSA, 2009). These stressors might have environmental, physical or psychological origin (Moore & Jessop, 2003). Stress related to hierarchy (Dobson & Smith 2000), high temperatures (De Rensis & Scaramuzzi, 2003) or aversive handling (Waiblinger et al., 2004) are some examples.

2) Or the opposite may happen, where impaired welfare is caused by reproductive disorders such as dystocia or metritis (EFSA, 2009).

There are infectious diseases that affect fertility, such as Leptospirosis, Johne's disease (paratuberculosis), bovine virus diarrhoea (BVD), Neosporosis (Esslemont & Kossaibati, 2000) and Brucellosis (Bartels et al., 2006). However, there are 'management/production diseases' that also affect reproduction and welfare and seem to be more menacing than the infectious diseases (Dobson et al., 2007). These 'management diseases' include mastitis, lameness, dystocia, metritis, retained foetal membranes, hypocalcaemia or undernutrition

(Sheldon et al., 2000; Dobson et al., 2001; López-Gatius et al., 2006; Von Borell et al., 2007; Garcia et al., 2011). Delayed resumption of ovarian cyclicity after calving might be one of the causes that relate these diseases to fertility, as in the case of inability to express oestrus in lame cows (reviewed by Dobson et al., 2007). Additionally, research has shown that one-sided genetic selection for higher yields has adverse effects on reproductive efficiency (Pryce et al., 2004; Dobson et al., 2007).

It is important to emphasize that reproductive failure can also be caused by factors that are not at all related with welfare, for example lack of oestrus detection or ineffective artificial insemination strategies.

Dairy farmers should seek to achieve:

1) having heifers calving for the first time with approximately 24 months (Esslemont & Kossaibati, 2000)
2) calving to first service (insemination) interval below 70 days (Esslemont & Kossaibati, 2000)
3) mean calving to conception interval ('days open', 'days non-gravid') should be lower than 120; this indicator can be calculated by subtracting 280 days to the calving interval (Esslemont & Kossaibati, 2000)
4) average calving intervals between 365 and 415 days (Costa, 2011), with less than 5% of the cows in a herd outside this range (Hartigan, 1995)
5) conception rate to first service should be between 30 and 60% (Costa, 2011)
6) number of services per conception should be between 1.5 and 3 (Costa, 2011)

According to McConnel et al. (2008), when the average calving interval of a herd is higher than 13.9 months (423.95 days), it is 1.78 times more likely to have a greater level of mortality than herds with average calving intervals lower than 13 months. Furthermore, Weigel et al. (2003) have shown that cows with fertility problems have higher chances of being culled. The hazard of culling has a peak 30 days after calving (or earlier for first-parity cows) and another after 280 days for older cows. Cows with greater parity had an increased risk for live culling and pregnant cows had lower hazards of culling than open cows. Also, the chance of being culled was increased for cows that had greater calving difficulty (De Vries et al., 2010). According to Hartigan (1995), about 6% of cows will not be pregnant after three services ('repeat breeders'), and that makes them probable targets for involuntary culling. This percentage should not be higher than 10%, and, to avoid it, four main objectives can be applied:

1) to ensure that first parities occur at approximately 24 months of age (Ettema & Santos, 2004);

2) to guarantee that the detection of oestrus is efficient and accurate, and there is a high submission rate (percentage of calved cows in a herd that are inseminated in the first 24 days [duration of an estric cycle] after uterine involution [40-70 days]; Stevenson, 2005);

3) to monitor uterine involution and the resumption of cyclic ovarian activity during the postpartum, so that the cow is prepared to start pregnancy soon after calving (Hartigan, 1995);

4) to detect and treat diseases that may impair fertility (Hartigan, 1995).

1.2.3.2.Mortality

There are three possible ends for a dairy cow:

1) It dies on-farm naturally (unassisted) or euthanized;

2) It goes to the abattoir for:

a. Regular slaughter

b. Sanitary slaughter – slaughter of animals suspicious or infected with bovine brucelosis, bovine tuberculosis and other diseases included in the Council Directive 2003/99/EC of 17 November (*Directiva 2003/99/CE de 17 de Novembro*)

c. Emergency slaughter – it is executed outside the abattoir by order of an official veterinarian whenever transport to the slaughterhouse will cause additional suffering to an animal that has experienced an accident or that has severe physiological or functional disturbance (*Portaria n.º 971/94 de 29 de Outubro*), for example pelvic or limb fracture, paralysis after dystocia or severe trauma (Veloso, 2011); non ambulatory animals should be slaughtered on site or transported through a trolley or movable platform and they should not be dragged (*Decreto-Lei nº 28/96 de 2 de Abril*)

3) It is sold to another farm.

According to Thomsen & Houe (2006), an increase of cows dying unassisted is a welfare problem (suffering before death). Moreover, research has shown that a high rate of on-farm mortality (i.e., euthanasia or unassisted death) is a potential indicator of poor welfare (Winckler et al., 2003; De Vries et al., 2011; Alvasen et al., 2012). On-farm euthanasia is a way of ending with uncontrollable animal pain, whenever transport to the slaughterhouse will cause additional stress and suffering. Downer cows, severely lame cows (e.g. fractured leg, irreparable), severe trauma and loss of production and quality of life, are some examples of the most common indications for on-farm killing (reviewed by EFSA, 2009). Regulation (EC) No 1/2005 prohibits the transport of unfit animals and Council Directive 93/119/EC requires that those animals should be slaughtered or killed on the spot to avoid unnecessary suffering. However, a final report of an audit performed in Portugal by the Food and Veterinary Office (FVO) had as an overall conclusion that "although there has been some improvement, action is still required in particular concerning veterinary practitioners signing incorrect declarations on fitness for recumbent or injured cows" (EC, 2011), since six cows in 18 delivered for emergency slaughter were unfit for transport in March 2011.

The age of those animals that are slaughtered can also say something about its welfare. Research has shown that high calf mortality until six months is a potential indicator of poor welfare in herds (Ortiz-Pelaez et al., 2008; Sandgren et al., 2009). Longevity is discussed on section 1.2.3.4 of this dissertation.

1.2.3.3.Carcass characteristics

In Europe, bovine carcasses are evaluated relatively to their conformation and amount of fat. The conformation is scored according to the SEUROP system, with S as superior and P as poor. The adiposity is scored from one to five, one being very thin, three as medium and five as very fat. Carcasses can also be divided in: A) less than two years old non castrated male carcasses; B) other male carcasses; C) castrated male carcasses; calved female carcasses; other female carcasses (*Regulamento [CE] nº 1183/2006 de 24 de Julho*).

A study of Minchin et al. (2009) demonstrated that more than 60% of dairy cows slaughtered in Ireland between September and November of 2005 failed to achieve the desired carcass standard, which consisted in having a cold carcass weight of 272 kg or more, conformation class of *P+* or more and a fat class higher or equal to three. Failure to accomplish any of the three parameters would lead to a reduction of the economic value of the carcass. It was assumed that the major fraction of those cows was not subjected to any special finishing treatment prior to slaughter.

Another study presented by Sogstad et al. (2007) showed that lameness was associated with a poorer carcass classification, as a consequence of reduced eating time and increment of catabolism (caused by pain). This conclusion stresses the impact of lameness on the economic losses for the farmer.

Rejection of carcasses is an important cause of economic losses for the farmer. Moreover, it can be easily related with welfare since its causes are commonly diseases discussed earlier in this dissertation (pneumonia, metritis, claw diseases). Carcasses might be partly or totally rejected. According to a report of ungulates' sanitary inspection in Portugal from October 2010 to August 2011 (DGAV, 2011), the main causes for bovine rejection (beef and dairy cattle) relatively to each type of slaughter were:

1) Regular slaughter rejection:

a. *Ante mortem* – hypothermia, hyperthermia/fever, agonic state;

b. *Post mortem* – pneumonia/pleurisies, osteitis, cachexia/hidrohemia, peritonitis, arthritis, multiple abscesses, general organic reaction, mastitis, neurofibromatosis, metritis/pyometra;

2) Sanitary slaughter rejection – bovine tuberculosis, nonnutritive meat, general alterations (e.g. cachexia);

3) Emergency slaughter rejection – traumatized meat, suspicion of drug administration, peritonitis, osteitis, general organic reaction, arthritis, metritis, general alterations (e.g. cachexia), hyperthermia/fever, necrotic miositis.

1.2.3.4. Longevity

The lifespan of a cow can be divided in two time periods, the first one from birth to first calving and the second one is the productive period, ending when the cow is culled or dies. The second period is also called longevity (Essl, 1998). Length of productive life has substantially decreased (from 80% to 60%) between the years of 1957 and 2002 and is still declining in intensively kept dairy cows (EFSA, 2009).

Culling is defined as the departure of cattle from the dairy farm (Fetrow et al., 2006) and it can be described as voluntary or involuntary. The first type is mainly related with healthy but low productive animals, while the second is related with loss of profitability due to infertility, disease or injury (Weigel et al., 2003). Nowadays, involuntary culling seems to be increasing in relation to voluntary culling, contrarily to what happened in the past (reviewed by FAWC, 2009b). This is synonymous of economic losses for the farmer and also a sign of poor animal welfare (Weigel et al., 2003). Moreover, by having to cull more animals than intended, farms will probably have to keep cows with problems (e.g. lameness) so as to maintain herd size and production level (FAWC, 2009b).

Culling can be affected by many factors such as: the aim of expanding a herd that can lead to keeping animals that would usually be culled; changing dairy husbandry system, where some cows do not adapt and have to be culled; adjustment of herd size because of milk quota and milk price policy factors; disease control (EFSA, 2009).

In a study performed by Barros (2013) in the south of Portugal, the main culling reasons were, by descending order, udder problems, reproductive failure and lameness. Contrarily to this, the studies of Pinedo et al. (2010) and Ahlman et al. (2011) performed in the United States of America and Sweden, respectively, concluded that reproduction was a more important cause of culling than mastitis.

1.2.3.5.Milk production

Half of the progress made in the individual level of milk yield is associated with genetics and the other half is associated with better nutrition, housing, health and management (Pryce et al., 2004). It has been shown that the occurrence of diseases can lead to a reduction in milk yield (Bareille et al., 2003), however high levels of production can also lead to increased incidence of disease and therefore to higher rates of involuntary culling (Fleischer et al., 2001). As is possible to conclude, the relationship between milk production and animal welfare is complex, thus when using milk yield to evaluate the level of welfare, the causes of change in production should be understood or it should be combined with other aspects of performance such as fertility and longevity (Calamari & Bertoni, 2009).

CHAPTER II – Welfare field study

Aims

The present study aims to determine the possibility of identifying dairy farms with poor welfare using a national cattle database, specifically, the National Database of Cattle Register and Identification (*Sistema Nacional de Identificação e Registo de Bovinos [SNIRB]*). Secondarily, it seeks to understand the major welfare problems in cattle dairy farms of the north and centre of Portugal and to test a welfare evaluation protocol that can be used to grade these farms.

2.1. Material and methods

2.1.1. Case study herd enrolment

Data from 24 dairy herds were included in this study. Thirteen of these farms were located in the centre of Portugal and 11 were located in the north of the country. Holstein–Friesian was the predominant breed. All farms used free-stalls with the exception of one, which was based on a loose-housing system. Two of the herds had 400-680 milking cows, seven had 200-398, nine had 100-198 and six had 20-95 milking cows. The selection of farms was not made randomly, it was made according to contacts already made through other veterinary students (center) and through a veterinarian that selected some of the dairy farms where he used to work (north). A total number of 1930 cows were assessed.

2.1.1.1. Farm visits

Each farm was visited once between January 2013 and March 2013, spending an average of one day per farm. All visits were conducted by one observer. The study methodology was based on the WQ protocol.

2.1.1.2. Cow selection and assessment

As suggested by the WQ protocol, cows were selected randomly, in the milking parlour. When it was not possible (automatic milking), they were selected in the feeding rack, choosing every n^{th} cow in the rows. The sample size was assessed according to the WQ protocol. No dry cows, or animals housed outside of the milking herd were examined.

2.1.2. Animal-based measurements – Application of the Welfare Quality® Assessment protocol for cattle

2.1.2.1. Clinical scoring

Animals were physically marked when selected in the milking parlour, to facilitate their identification in the pens. The animals' identification number would also be registered.

Selected cows were scored for udder and lower hind leg cleanliness and integument alterations in the milking parlour. Then, selected animals would have a second classification in the facilities where they would be scored for integument alterations in the hindquarter (including tail), flank, front leg and back (including neck, shoulder and head). The cleanliness of flank and hindquarter would also be scored. Signs of disease were searched at that time, such as diarrhoea, vulvar, ocular and nasal discharges. The body condition and locomotion score were also assessed and evaluated in a three scale classification, according to the rules of WQ protocol. A cow would be considered moderately lame if there was "an imperfect temporal rhythm in stride creating a limp", and severely lame if there was a "strong reluctance to bear weight on one limb, or more than one limb affected" (WQ, 2009).

Cleanliness and integument alterations were scored only on one randomly chosen side of each animal. When scoring cleanliness, the body region was considered dirty if there was a quantity of dirt with at least the size of the palm of the hand or, in case of the udder, if there was any dirt on and around the teats. Integument alterations were divided in hairless patches (alopecia or thinning of the coat), lesions (scabs, wound, dermatitis, ear lesion due rips caused by ear tags) and swellings.

2.1.2.2. Social behaviour

Another time consuming measure is the behaviour evaluation, which lasts 120 min, whichever the size of the herd. To do this evaluation, it is necessary to divide the group herds in representative segments (with 25 cows max) that cannot exceed a total of 12. According to the number of segments that the evaluator has determined, there is a repetition of the observation of the same segment. If there are between eight and 12 segments, no repetition is performed, but if there are between two and six, the observation should be repeated, but always performing a total net duration of 120 min. The evaluator defines a fix observing point and the limits of the segment. The animals that are lying are counted, as well as those standing. It is registered how many are lying outside (completely or partly) and how many have their hindquarter not visible from the observing point. At the end of the observing time, cows that are within the limits established are counted again, according to the same criteria. During the observation time, the evaluator looks for agonistic interactions, records the number of coughing and checks the time that cows need to lie down and if they collide against the cubicles while lying.

2.1.2.3. Qualitative behaviour assessment (QBA)

The QBA is another tool to score animal behaviour, where the evaluator rates 20 adjectives, on a scale of 125 mm, according to the overall general behaviour of the herd (Annex 2). This evaluation is based on memory and is not done while observing the animals. The terms with higher positive weight in the WQ protocol are 'happy' and 'content', and the ones that influence more negatively the final score are 'irritable' and 'distressed'.

2.1.2.4. Avoidance distance

To evaluate de human-animal relationship, the WQ protocol set has elected the avoidance distance test. This test consists in an approach of the evaluator towards the selected cow, starting at a 200 cm point. The cow's head must be totally past the feeding rack. The evaluator gives one step (of approximately 60 cm) per second, with his arm at an angle of 45º from the body. When the cow moves back (or turns the head to the side or tries to get out of the feeding rack), the evaluator estimates the distance between his hand and the muzzle of the animal, with a resolution of 10cm. If the animal is touched, the distance recorded is 0 cm.

2.1.2.5. Water points

The absence of prolonged thirst is scored according to the type, dimension, cleanliness and functionality of the water points.

2.1.2.6. Management questionnaire

Finally, there is a questionnaire to the farmer to collect information about management procedures (disbudding, tail docking, grazing) and health records. The evaluator gets to know the mortality of the milking herd (died on-farm, were euthanized or were emergency slaughtered), dystocia and downer cows of the last 12 months and the presence of mastitis in the three months prior to the farm visit (Annex 2).

The farm identification number is also obtained in this questionnaire, and it is of major importance since it will allow us to identify the farm within the national dataset, therefore linking the welfare classification of that farm with the potential national welfare indicators.

2.1.2.7. Alterations made to the Welfare Quality® protocol

Opposing to the WQ protocol regulations, in order to facilitate the evaluation, any visual integument alteration was scored (and not only those with a diameter equal or greater than two centimetres) and missing teats were not considered a lesion. Another alteration made to the WQ protocol was the non-evaluation of dry cows, because most times these animals were kept in distant pens and the evaluation would be too time-consuming. Because sometimes there was little time to perform the WQ on all dairy cows selected on the milking parlour, the evaluator had to focus on scoring the selected lactating cows rather than 'losing' some of this data by spending time evaluating dry cows. Additionally, evaluation of the udder and lower back legs is easier to carry out in the milking parlour, where these body regions are at eye level, thus it is probable that lactating cows are always better evaluated than dry cows on this point.

Finally, according to the WQ protocol, time needed to lie down requires a minimum sample of six cows to get a value, however in some farms that was not possible to accomplish, and measures collected were used to the final calculations to avoid losing this information.

2.1.2.8. Calculation of scores

Once all the measures have been collected on the dairy farm, the purpose is to produce an overall score of animal welfare to each farm. The overall assessment is obtained from the calculation of the four principles, 'Good feeding', 'Good housing', 'Good health' and 'Appropriate behaviour'. These principles are calculated by the combination of the criterion scores, which are based on the collected indicators (see Table 1).

Criterion scores are calculated differently depending on the measures they are based on. They can be calculated through decision trees, weighted sums, or by comparing measures with alarm thresholds. The criterion result is expressed on a 0 to 100 value scale, in which 0 corresponds to the worst situation, 50 corresponds to a neutral situation and 100 is the best situation. When referring to a group level, the score attributed to the farm is the worst score obtained between groups as long as the number of animals performs 15% of the total herd.

Principle scores are calculated from criterion-scores through the use of choquet-integrals. Each principle is excellent when it scores 80 or more, enhanced if it scores at least 55 and acceptable when higher or equal to 20.

The final score of the farm is based on the four principle scores. A farm is considered (WQ, 2009):

1) 'excellent' if it scores more than 55 on all principles and more than 80 on two of them – the welfare of animals is the highest
2) 'enhanced' if it scores more than 20 on all principles and more than 55 on two of them – the welfare of animals is good
3) 'acceptable' when three of the principles have a score higher than 20 and the other has more than ten – the welfare of animals meets minimal requirements
4) 'not classified' when it does not achieve any of the classifications mentioned above – the welfare of animals is low and considered unacceptable

A bad scored principle cannot be compensated by a good scored one, so categories cannot be based on average scores.

2.1.3. Data sources for potential welfare indicators

At the end of 2012, a subset of data concerning the time between 01/01/2008 and 31/12/2011 was extracted from *SNIRB*. The data subset included the following tables:

1) Live cattle;
2) Births;
3) Herd movement records;
4) Records at slaughter.

These tables' content is presented on Table 4.

2.1.3.1. Choice of potential welfare indicators from the data sources

The following variables were calculated from the original data:

1) Age at first calving (months);
2) Proportion of calving intervals lower than the biological (345 days) and proportion of calving intervals higher than 430 days;
3) Calf mortality (until six months);
4) Mortality rate;
5) Proportion of on-farm deaths;
6) Proportion of emergency slaughter;
7) Total life span (months);
8) Proportion of cows slaughtered at 30 and 60 days post partum;
9) Proportion of partial and total carcass rejection;
10) Proportion of carcasses with less than 272 kg;
11) Proportion of carcasses with fat class 'very thin' (class 1);
12) Female/male births ratio.

Table 5 presents source tables, selection parameters and period, formula and number of records of the potential welfare indicators. Variables were calculated for the overall results from Portuguese dairy farms. Therefore, selection of dairy farms was made by selecting cows from the dairy breeds list of *SNIRB* namely, 'Freisian', 'Pie Rouge', 'Norwegian', 'Jersey', 'kind Freisian', 'Milk Ind' and 'Piedmonts'. Consequently, 17,649 dairy farms were identified. This number was reduced to the farms that had at least five cows, similarly to the dairy farm selection method of *DGAV*, resulting in a number of 6,605 dairy farms.

2.1.4. Data analysis

The final welfare scores (WQ protocol) were calculated using Microsoft Office Excel 2007. Data obtained on the 24 farms evaluated by the rules of the WQ protocol was statistically analyzed using R i386 3.0.0.. Spearman rank correlations were used to determine relationships between welfare measures. Differences between WQ measures from poor and good welfare farms were examined with t-test.

The multiple correspondence analysis (MCA) method was used for an exploratory analysis of the association between the classification of each principle and of each criterion with the final welfare score of the evaluated farms. This method produces a graphical representation of the lines and columns of a contingency table, enabling the graphical analysis of the existing relationships by reducing the dimensionality of the data (Johnson & Wichern, 1998).

Data extracted from *SNIRB* was used to calculate potential welfare indicators using Microsoft Office Access 2007, with the exception of calving intervals, that were calculated using R i386 3.0.0. To evaluate if there was a significant difference on potential welfare indicators between good and poor welfare farms, a two-sample Wilcoxon test was used. Moreover, spearman rank correlations were used to determine relationships between welfare measures (WQ protocol) and potential welfare indicators and between potential welfare indicators from the 24 dairy farms.

The model to detect farms with poor welfare was created using Waikato Environment for Knowledge Analysis (WEKA 3.6.9). This is an open source software that allows to convert large amounts of data into meaningful patterns and rules, which is called ‘data mining’.

In this study, the number of farms with poor and good welfare is very uneven and the differences between them are not significant (Table 6, 7 and 9). A way of reducing the disproportion between the two groups of farms is by using the Synthetic Minority Over-sampling Technique (SMOTE). This method over-samples the minority group and under-samples the majority group. By doing that, when classifying the minority class, it is possible to get an increment on its sensitivity. The over-sampling of the minority class is done by producing ‘synthetic’ examples (Chawla et al., 2002).

After balancing the dataset with SMOTE, it is possible to create a more accurate model do detect farms with poor welfare. WEKA offers two major methods for data mining – classification (decision tree) and clustering. The first one has the advantage of being easy to interpret, and it is the one that will be used in this study (Abernethy, 2010). To build decision trees, one of the most well-known classifiers in WEKA is J48 (Quinlan, 1992), which is a good method for small datasets (Ali et al., 2012). J48 acts by: 1) building a decision tree based on the entire given dataset; 2) splits the data into smaller subsets by testing for a given attribute; 3) identifies the attributes that discriminates the various cases most clearly (those that ‘have the highest information gain’.

2.2. Results and discussion

2.2.1. Welfare Quality® protocol application in Portuguese dairy farms

From the 24 farms, only one was scored as ‘enhanced’, the majority (18 farms) was scored as ‘acceptable’ and five farms were ‘not classified’. They have been divided in two groups: farms with ‘good welfare’ that are those scored as ‘enhanced’ and ‘acceptable’ and farms with ‘poor welfare’ which are the ones ‘not classified’. Collected data is summarized in Table 2. Similarly to results from other countries, no farm was scored as excellent (Ostojić-Andrić et al., 2011; Popescu et al., 2013).

Welfare principles	Principles classification (0-100)	Welfare criteria	Criteria classification (0-100)
Good feeding	37.45 ± 29.58	Absence of prolonged hunger (Lean)	86.72 ± 14.30
		Absence of prolonged thirst (Water points)	32.12 ± 35.24
Good housing	54.89 ± 18.60	Comfort around resting (LD, LC, LO, DHQ, DLL, DU)	28.40 ± 29.53
		Ease of movement (Tethering)	100 ± 0
Good health	18.67 ± 6.83	Absence of injuries (ModL, SevL, NIA, YMA, YSA)	15.63 ± 6.76
		Absence of disease (Cough, Nas, Ocu, Vulv, Diar, Hamp, Mast, Mort, Dyst, Down)	32.02 ± 17.15
		Absence of pain induced by management procedures	26.61 ± 19.51
Appropriate behaviour	21.94 ± 6.98	Expression of social behaviours	67.60 ± 17.83
		Expression of other behaviours (pasture)	1.19 ± 5.81
		Good human-animal relationship (AD)	45.20 ± 13.43
		Positive emotional state (QBA)	40.48 ± 22.12

Table 2 – Principles and criteria classification (means ± SD).

2.2.1.1. Good feeding

a) Absence of prolonged hunger

This criterion had an average classification of 86.72 (Table 2), as result of a very low percentage of lean cows, close to 2% in both good and poor welfare farms (Table 6).

The study of Jacinto (2011) performed in 9 Portuguese dairy farms in almost 600 animals, also resulted good BCS results in terms of welfare, with an average BCS of 3.28 (using a five point scale).

Most studies quantify BCS at specific moments in lactation, however the WQ protocol directs to a BCS assessment at a random moment in lactation. That might be a problem since cows’ BCS vary a lot along the lactation. According to Chagas et al. (2007), a cow should calve with a BCS of 3.25 and during the first two months of lactation, suffers a loss in body condition than can go to 2.5, due to the negative energy balance. At a 2.5 BCS pins and hooks are angular and ribs can be seen, and these are three parameters than could lead to a classification ‘very lean’ in the WQ protocol. However diminishment in cow’s BCS at the peak of lactation cannot be avoided and it is not a sign of prolonged hunger but a sign of the negative energy balance that is acceptable in low degree.

b) Absence of prolonged thirst

The classification was: excellent in four farms (three of them from the north); enhanced in two farms that did not have at least two drinkers available in the pen; acceptable in nine farms, in which the drinkers were normally dirty and the number of functioning drinkers was partly sufficient; and 'not classified' in nine farms (six of them from the centre), that did not have an enough number of functioning drinkers. This leads to an average score of 32.12, which is 'acceptable' on terms of welfare (Table 2).

From all the 24 farms, half had their drinkers dirty, which was shown to be the main problem in the farms visited. The insufficient number of drinkers in nine farms was also an issue, this one with worst consequences for the welfare of dairy cows, not only related with higher agonistic encounters, but also related with the possible presence of thirst in the more submissive animals and in hot weather.

It is important to emphasize that a farm obtains the worst score on absent of prolonged thirst when at least 15% of animals (a group within the herd) is classified with that score (WQ, 2009). It brings up the question if it is fair to score this criterion as 'not classified' in a farm that has 85 cows in the best of the conditions in terms of water supply and 15 cows in the worst.

2.2.1.2. Good housing

When compared with the other principles, this was the one with the best average score, 54.89 (Table 2).

a) Comfort around resting

The comfort around resting was classified as excellent in two farms (from the center), enhanced in three farms, acceptable in four farms and 'not classified' in the other 15, of which ten were located in the north of Portugal.

Lying outside the stall

The number of cows lying outside the stall (LO; partially or completely) was a 'problem', (more than 3%) in three farms and a 'serious problem' (more than 5%) in 11 farms, of which nine were located in the north of Portugal. It is possible to see in Table 6 that the average of LO on farms with 'good' and 'poor' welfare are higher than the target values. This can be a sign of lower number of cubicles compared to the number of cows, cows that are not used to lying on cubicles or, more commonly, cubicles that are too small in relation to cows' size or that are in poor conditions (e.g. uncomfortable bedding, disrupted mattresses, damaged cubicle barriers). It is known that Holstein–Friesian have become bigger with the passing of years, as a consequence of selection for increased ingestion capacity leading to higher milk production. Oltenacu and Broom (2010) stated that, clearly, these changes in cows' body affect the space needed to perform their movements freely, however there are many farms in Portugal that are handed through generations and are not prepared for these high-producing cows.

Time needed to lie down and collisions with equipment

As was stated before in this study, the WQ protocol refers that a minimum sample size of six animals is required for these measures. However, that was accomplished in only 15 farms out of the 24. Nevertheless, values of the other nine farms were used on the welfare evaluation, so that data would not be lost. From those farms, one had a sample of five animals, three had a sample of four, three had a sample of three animals and the other two had a sample of one or two animals.

Six farms had a problem (>5.2 seconds) for time to lie down, and two had a serious problem (>6.3 seconds). It is possible to see in Table 6 that the averages are not superior to 5.2 seconds, but they are higher in good welfare farms (5.24 seconds) than in poor welfare farms (4.93 seconds). This could be related with the failure in getting the minimum sample of six cows in some farms. Contrarily to this, collisions while lying were much higher in poor welfare farms (34%) than in farms with good welfare (20%). Five farms had a problem (>20% cows colliding against the cubicles) and seven had a serious problem (>30%). This is a main issue found in the evaluated farms, since half of them had at least 20 percent of cows colliding against the cubicles. It shows that there might be insufficient cubicle size, or cows suffering from lameness.

Dirtiness

The percentage of cows with dirty lower legs was a 'problem' (>20%) in nine farms and a 'serious problem' (>50%) in five of the 24 farms. This resulted in an average of 32% in 'good' farms and 17% in 'poor' welfare farms.

The udder was the dirtiest of the three body regions, with averages of 37% and 59% for poor and good welfare farms, respectively. Twenty farms were considered as having a 'serious problem' (>19%) and the other four as having a 'problem' (>10%) on this matter. Similarly, the dirtiness of the hindquarter was a 'serious problem' (>19%) in 18 farms and a 'problem' (>10%) in two.

These results show that, in general, since the animal's cleanliness is a reflection of its environment, the visited farms might be too dirty as a result of low frequency of scraping the floor, or cleaning/replacing the bedding.

It is strange, however, that none of the evaluated farms had less than 10% of their animals with dirty udders, since it is so closely related with milk hygiene and quality. It is possible that the WQ protocol exaggerates when considering that the udder should be considered dirty when there is "any dirt on and around the teats", even if the rest of it is clean. Other classifications (e.g. Cook, 2002) are not as rigorous, stating that the worst score (four) is given when there are "confluent plaques of manure encrusted on and around the teats". However, other study that has used the WQ protocol (Popescu, 2013) had the opposite result, with hindquarter and flank being the most frequently dirty area, then lower legs and lastly, the udder. Another one done in Portugal by Jacinto (2011) had also lower percentages of dirty udders (6.6%), with lower back legs and hindquarter/flank as the dirtiest regions (60.5% and 17.7%). Therefore, this result may be caused by the evaluator's interpretation of what is considered "any dirt" on the teats.

b) Ease of movement

The ease of movement was scored as 100 (excellent) for all the 24 farms, because none of them had tied animals.

2.2.1.3. Good health

In one farm it was not possible to obtain the result on the criterion 'Absence of pain induced by management procedures', therefore the principle of 'Good health' was calculated by replacing 'Absence of pain induced by management procedures' by the best score between the criteria 'Absence of injuries' and 'Absence of disease'. This is the solution that the WQ protocol suggests for the case of the missing criteria 'Thermal comfort' on the principle of 'Good housing'.

a) Absence of injuries

The average score for absence of injuries was 15.63 with a low standard deviation. Nineteen farms were 'not classified' and five farms were scored as 'acceptable'. The causes for the low score of this criterion are easily understood by looking at Table 6, where the average presence of severe integument alterations (YSA) is very high, with values close to 70 and 80% in good and poor farms, respectively. Moderate lameness is also particularly high, close to 40%, when compared to severe lameness (close to 10%).

To calculate the final score for absence of injuries both integument alterations and lameness are scored separately, making a partial score for each one. The calculation of lameness partial score is done according to the weighted percentage of cows with moderate lameness and cows with severe lameness, with weights of 0.29 and 1, respectively.

In order to understand the results on integument alterations, Figure 1 represents the results obtained for integument alterations on five body areas, as does Table 7. Integument alterations on the flank were excluded from these, being considered less significant than the other areas.

Integument alterations

Animals with no integument alterations were rare. On six farms all the animals had integument alterations. On the other hand, there were two farms where more than 10% of the animals did not have any kind of integument alterations, however this does not necessarily mean that these farms have animals in better conditions, because the visualization of such alterations can be difficult when the environment is without sufficient light, when animals are too dirty, or when they are too fearful and do not let the evaluator get close enough to see the smaller integument alterations.

Almost every cow had at least one hairless patch. Looking at Figure 1 it is possible to see that the most affected body region is the lower back legs (HPLBL), with an average higher than 80% (Table 7), followed by the lower front legs (HPLFL) and the hindquarter (HPHQ). These results are in agreement with those of Potterson et al. (2011), in which the average percentage of hocks per herd displaying hair loss was 91.7%, with a minimum of 39.6% and a maximum of 100%.

Tuber calcis and the lateral tarsal joint were the regions within the lower back leg where presence of hairless patch was more frequent, similarly to the results of Weary and Taszkun (1999). Figure 11 illustrates different degrees of hairless patches in those common places.

As stated before in this dissertation, severe integument alterations include lesions and swellings. Lesions can have many degrees of severity and size, but the WQ protocol classification does not include these differences. The same happens with swellings. Lesions and swellings vary in location and each location in the body represents a specific problem frequently associated with the premises. Once again, lower back legs were the most affected in terms of presence of lesions (LLBL), with averages close to 40%. The hindquarter was the second most affected (LHQ), followed by the lower front legs (LLFL).

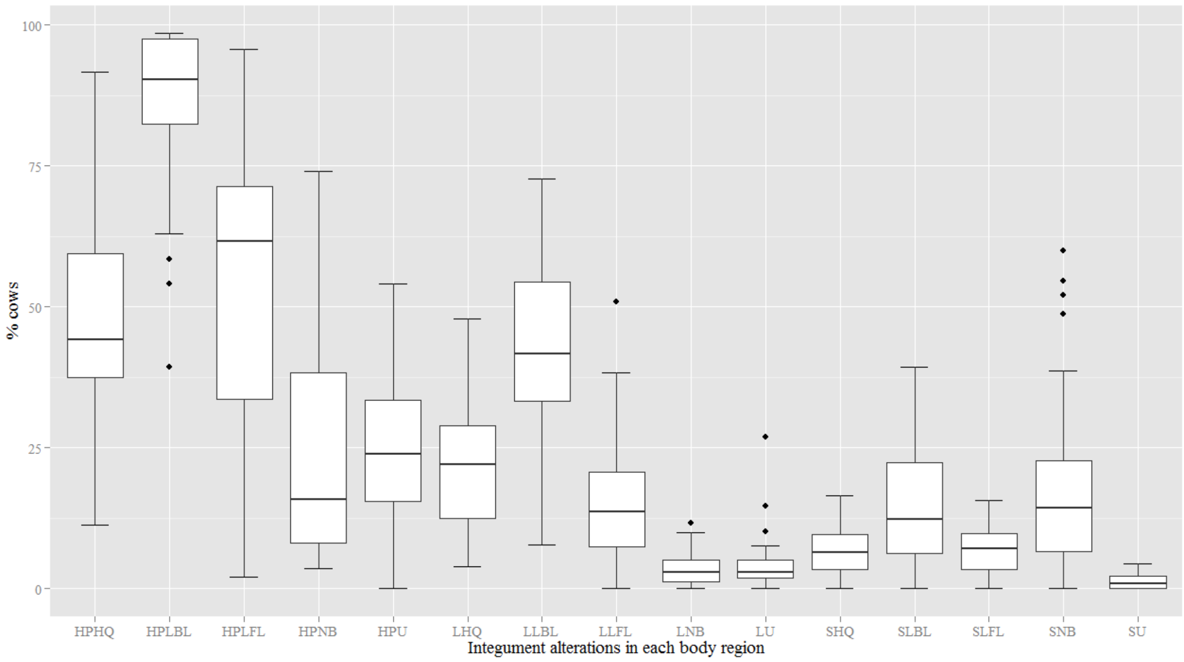

Figure 1 – Distribution of cows with integument alterations on the 24 farms evaluated. (●) are outliers. Key to acronyms: HPHQ, hairless patch hindquarter, HPLBL hairless patch lower back leg, HPLFL, hairless patch lower front leg, HPNB, hairless patch neck/back, HPU, hairless patch udder, LHQ, lesion hindquarter, LLBL, lesion lower back leg, LLFL, lesion lower front leg, LNB, lesion neck/back, LU, lesion udder, SHQ, swelling hindquarter, SLBL, swelling lower back leg, SLFL, swelling lower front leg, SNB, swelling neck/back, SU, swelling udder.

In regards to swellings, the neck/back area (SNB) was more affected than the lower back legs (SLBL) on farms with poor welfare, with an average of 35.84% and 15.99%, respectively (Table 7). However, when looking at the total of the farms evaluated (Figure 1), averages between swellings in both areas were very similar.

Similarly to these results, Popescu et al. (2013) observed lesions and swellings especially in the hock region (lower back legs). A study carried out in UK concluded that the presence of severe hock lesions was one of the main welfare problems of large dairy farms (Haskell et al, 2005).

Udder hairless patches were frequently related with its size, given that the inner part of the hind legs produces friction against very large udders, when cows walk. Other integument alterations in the udder could be related with the stall surface or with mastitis. Integument alterations in the lower back legs and lower front legs were probably related with the type of bedding used in the farm and with its state of conservation. In the hindquarter and back, there would probably be more than one possible origin, since location sometimes varied between farms. Some were consistently present in the tail head and were accompanied by lesions of dermatitis, similar to those caused by *Chorioptes bovis* (Figure 12), a mite that normally appears in the winter months. Other hairless patches were possibly related with the stall surface, inappropriate milking parlour design (where bars make pressure against cow's body while being milked) or to the excessive use of the pen-installed brushes. The collision against the cubicle bars while lying down and the pressure exerted on them while resting could also cause some integument alterations presented in the back. Cows that are mounted by herdmates (cows in heat) may also present hairless patches in the hindquarter, particularly in the dorsal zone. Finally, integument alterations in the dorsal part of the neck (Figure 13) might be caused by pressure against low feed-rails (compared to the size of the cow) while eating (Zurbrigg et al., 2005) or by colliding against the crossbeam while getting up from the cubicle, in small size resting areas.

Lameness

The average presence of moderate lameness was 44% and 38% for poor and good farms, in that order. The mean percentage of cows severely lame was lower, being of 14% and 11%, respectively (Table 6).

A study performed by Jacinto (2011) in nine Portuguese farms presented a similar result for severe lameness, 14.2%. The average percentage of animals presenting lameness was 21.8%.

As stated before in this dissertation, the use of concrete floors and uncomfortable stalls, the lack of functional foot trimming and very large udders are some possible explanations for an excess of lameness in a herd.

Lameness assessment differed in localization between farms, with some cows being assessed in the milking parlour and others being assessed in the pen area. It depended mostly on the time spent by the workers doing the milking procedures, when there was plenty of time the evaluator could make the first part of clinical scoring and then calmly evaluate other measures of the second part of clinical scoring (that are usually done in the pens) such as locomotion. This difference in work area could make a difference, since in the milking parlour locomotion would be assessed at eye level, and in large milking parlours that would allow a 'long time' evaluation for each cow. Whereas in the pens sometimes the evaluation would have to be very quick, since frightened cows could move away immediately. Moreover, some farms had high animal density, with little space for a good view of cows' locomotion, and others had very slippery floors where locomotion was difficult for the cows. All these factors can underestimate or overestimate the percentage of lame cows.

According to the WQ protocol, irregular foot fall, imperfect temporal rhythm between hoof beats and reluctance to bear weight on at least one limb are the three indicators of lameness. It does not include arched back as an indicator, which is usual on traditional lameness assessment protocols (Sprecher et al., 1997).

b) Absence of disease

This criterion had an overall average score of 32.02 ± 17.15. It represents the combination of nasal, ocular and vulvar discharges, hampered respiration, coughing, presence of diarrhoea, mastitis, dystocia, downer cows and mortality. Unfortunately, some farms did not have the records of some of the measures included in the questionnaire (Annex 2), therefore this criteria was sometimes calculated only on basis of the measures that were possible to obtain.

Nasal discharge

There are nine farms with 'warning' (≥5%) for nasal discharge, and 12 farms with 'alarm' (≥10%). Average scores on both good and poor welfare farms were higher than the 'alarm' limit.

This measure is very vague, since all kinds of nasal secretions are included here. A simple mucosal nasal discharge without any other clinical signs (respiratory or systemic) can be irrelevant.

Coughing

Twenty one of the 24 farms had an 'alarm' (≥0.06) for coughing, and there was one farm with 'warning' (≥0.03). These results varied a lot in good farms (0.13 ± 0.09 mean coughing per cow per 15 minutes) and less in poor welfare farms (0.10 ± 0.02 mean coughing per cow per 15 minutes).

High coughing prevalence does not necessarily mean disease, because sometimes cows cough while drinking (or eating). However, these results are problematic under the WQ protocol guidelines, since almost 90% of the farms visited had alarming results on coughing. When combining these results with those of nasal discharge, it shows that management practices in relation to respiratory diseases might be poor. Moreover, pneumonia is the main cause of post mortem rejection in regularly slaughtered cows (DGAV, 2011), therefore respiratory disease might be a problem that needs further investigation in Portuguese cattle farms.

Hampered respiration

Results on hampered respiration were practically null. These results would probably be different in the summer, with some cows with breathing difficulty because of the high temperatures that are common in many regions of Portugal. The presence of fans, appropriate ventilation and sufficient drinkers are crucial in that season to avoid lower feed intake and milk production (Albright & Arave, 1997).

Ocular discharge

None of the selected farms had a significant percentage of ocular discharge. Sixteen of the 24 farms had 0% and the averages for both good and poor welfare farms were lower than 1%.

The threshold for 'warning' would be 3% of cows with ocular discharge and for 'alarm' it would be 6%.

Diarrhoea

The WQ protocol defines diarrhoea as "loose watery manure below the tail head on both sides of the tail" (WQ, 2009), which can be difficult to differentiate from pure dirtiness of the hindquarter in those farms that have a very high percentage of dirty animals. Two farms had more than 6.5% of animals with diarrhoea ('alarm') and five farms had a percentage equal or higher than 3.25% ('warning'). The average was 1.4% for farms with poor welfare and 2.7% to farms with good welfare. This difference was not statistically different (Table 6), but a possible reason for this unexpected disparity could be the higher concentrate/forage ratio in good farms with many high producing cows, leading to subclinical acidosis associated with diarrhoea.

Vulvar discharge

There were two farms with 'warning' (≥2.25%) and three with 'alarm' (≥4.5%) for vulvar discharge. The average percentage of cows with vulvar discharge was 2.1% in poor welfare farms and 1.5% in those scored as good. Eight farms did not have signs of this discharge (0%).

Cows were evaluated standing, but sometimes the evaluation started with them lying down and then they would be forced to stand up so that the evaluation of the body condition, lameness and integument alterations in the lower front legs would be possible. A vulvar discharge would be easily seen in a recumbent cow with metritis because of the higher abdominal pressure, however if it would be only evaluated standing, that sign would be hidden, which could have underestimated the occurrence of on-farm metritis.

Mastitis

From the 24 farms, 21 responded to the questionnaire. Three farms did not normally perform the milk quality evaluation, therefore somatic cell count was possible to obtain only on 18 farms. Mastitis (Mast) percentages shown in Table 6 were calculated from three farms with poor welfare and 15 farms with good welfare. The warning threshold for mastitis is 8.75% of cows with somatic cell count over 400 (x1000/ml) and the alarm is 17.5%. The average percentage of cows with subclinical mastitis in good farms was 14% ± 7.2, while poor welfare farms had a mean value of 20% ± 24.4, which is higher than the alarm threshold. The increased standard deviation (SD) for poor welfare farms is related with the maximum value of 48.1% on one of the farms. Results for mastitis are concerning, since they are generally higher than the warning threshold. This can be a sign of bad management procedures in the milking parlour, bad biosecurity or ineffective treatment of infected cows.

Dystocia and downer cows

Records for dystocia and for downer cows were available from 12 of the 24 farms. Averages in good farms were a result of nine farms for dystocia and ten for downer cows. Therefore the number of records for farms with poor welfare is small, however, it is possible to see in Table 6 that dystocia is clearly higher in poor compared with good welfare farms, with ‘poor’ farms crossing the ‘warning’ threshold (2.75%) with an average of 4.2% dystocic cows, while good farms present a value of 2.7%. The contrary happens with numbers of downer cows, where poor welfare farms show an average of 2.7%, remaining below the limits, and good farms present 4.6%, higher than the warning threshold (2.75%). The alarm threshold is 5.5% for downer cows or dystocia.

A possible explanation for the higher prevalence of downer cows in good than in poor welfare farms is that the first might have a higher number of highly productive cows, which are those that are more likely to develop milk fever (hypocalcaemia), one of the major causes of the downer cow syndrome (Herdt, 1999). However this is only an hypothesis, since, as stated earlier, the relationship between milk production and welfare is complex.

The majority of the farms visited did not have the routine of describing these kinds of events. Values for both percentage of dystocia and percentage of downer cows were answered on basis of what the farmer remembered from the year before. This reality shows that Portuguese farmers have insufficient book keeping and probably do not see the importance of recording these and other disorders.

Therefore another possibility for a higher level of downer cows in good than in poor welfare farms is that farms considered as having good welfare were those that made more reliable records.

Cow mortality

Records on mortality were possible to get on 15 farms, of which 12 farms were scored as having good welfare and three were scored as poor. Mean percentages were 10.2% ± 4.1 for farms with good welfare and 9.7% ± 2.9 for farms with poor welfare. These averages are higher than the threshold for alarm, which is 4.5%. Even minimum values (6.75% for poor, 3.56% for good welfare farms) are higher than the limit for warning, which is 2.25%. The maximum value mortality value achieved was 16.6%.

When compared with results from a study performed by Barros (2013) in 12 Portuguese dairy farms, the average mortality rate (9%) is very similar to this study, with a minimum of 2% and a maximum of 25%.

It is possible to conclude that mortality is high, when compared to the WQ thresholds. Moreover, farms scored as having good welfare had higher mean averages of mortality than farms scored as having poor welfare. One possible reason for the higher mortality in good farms is that good farms might have more valuable productive cows and a more intensive feeding than farms with poor welfare. That could have two consequences: a higher incidence of metabolic diseases, such as ketosis or fatty liver syndrome and a tendency for prolonged treatments to avoid culling, that could lead to a higher number of on-farm killing.

c) Absence of pain induced by management procedures

The average overall score for this criterion was 26.61 ± 19.51, a mean value that corresponds to an acceptable state of welfare (Table 2).

Results were not possible to get on one farm. From the other 23 farms, only one did not perform disbudding, being scored with the maximum score in this criterion (100). Nine farms used caustic paste getting a score of 20, with one of them using a non-steroidal anti-inflammatory then scoring 41. Eleven farms preferred the use of thermocautery scoring 28 points, with two farms applying a local anaesthetic therefore getting a good score of 52. Two farms used a different method, amputation with scoop, without using anaesthetics or analgesics (there is no score given in the WQ protocol for other methods of disbudding, therefore the author has used the score two, which is given to dehorning in adults). The average age to perform disbudding was 6.12 weeks, with a maximum of 12 and a minimum of two weeks.

Tail docking was commonly performed on two farms, resulting in a score of three points in 100.

From these results it is possible to conclude that, in general, Portuguese farmers do not invest in anaesthetics or analgesics to reduce pain related with dehorning. The use of thermocautery was a little higher than the use of caustic paste, contrarily to the unpublished data from Stilwell, 2007, where caustic paste was the preferred method in Portuguese farms (reviewed by Stilwell, 2009b). Tail docking was performed in two of the 23 farms, showing that although in low percentages, it is still performed in Portugal.

2.2.1.4.Appropriate behaviour

a) Expression of social behaviours

The calculation of 'expression of social behaviours' score is done according to the weighted percentage of head butts and displacements, with weights of 0.36 and 1, respectively.

Generally, the expression of social behaviours was well scored, with seven farms scored as 'excellent', 12 farms as 'enhanced' and five as 'acceptable', lower scores representing higher agonistic behaviours. The average score was 67.60.

Displacements were mainly performed in the feed rail, and automatic feeding machine. For example cow A would be eating and cow B would head butt it (normally in the belly) until A leaves that space to B. Other possibilities would be when a cow in a cubicle would be expelled from it by other cow in a similar way to one described before, or when a cow was mounted by a herdmate (cows in heat) and that would make it walk or run away.

Head butts would be performed in the belly when the purpose was to make the other cow move away, and head to head when cows were eating, lying in adjacent spots or were starting a fight. Head butts and allo-grooming were commonly watched together, mainly when cows were eating in adjacent points.

It was possible to observe by the evaluator that expression of social behaviours is influenced by presence of cows in heat, automatic feeding machine with concentrate (including those linked to the automatic milking machine), drinkers and feed rail when these are in an insufficient number according to the number of cows in the pen, presence of brushes, small space for their body in the feeding zone that does not allow a cow to pass when another is eating, curious cows (that try to smell, lick, head butt, look at the evaluator and compete with herdmates to do so) and high density. Another factor that affects the quantity of agonistic behaviours observed in the segment is the number of cows that is eating at the time of evaluation.

Even with so many possible competition points, averages of displacements (0.46 good farms; 0.63 poor farms) and head butts per cow per hour (0.39 good farms; 0.36 poor farms) were low when compared to the extreme situation of 1.6 butts and 3.4 displacements per cow per hour proposed (WQ, 2009).

b) Expression of other behaviours

Results were obtained from 23 farms. From these, only one had dairy cows on pasture during some parts of the year, in this case it was during the dry period and for 24 hours a day. This calls attention for the lack of use of pasture for dairy cows in north and centre of Portugal and for the need for communicating to those related with dairy husbandry the advantages of allowing the outdoor access at least in some periods of the year.

c) Good human-animal relationship

As was previously described, the human-animal relationship was evaluated through the avoidance distance test. The average percentage of animals that could be touched was 31.16% in poor welfare farms and 37.17% in the good ones. Average percentages were also higher in good than in poor welfare farms with respect to avoidance distances between 0 and 50. The contrary was true to the avoidance distances from 50 to 100 and higher than 100.

On farms where the majority of animals is very fearful, it is possible that the score for the avoidance distance test does not give the real image of the fearfulness of the animals because as soon as the evaluator gets close to the feed rail almost all of the cows backup, and only the less fearful remain.

d) Positive emotional state

The average score for the qualitative behaviour assessment (QBA) was 40.49 (Table 2). Seven farms were classified as ‘enhanced’, 12 farms were ‘acceptable’ and five farms were ‘not classified’. None of the farms had an excellent score (over 80) and 15 farms had a score lower than 50. Therefore it is possible to conclude that the QBA scores were generally poor.

It happens that behaviour varies a lot if the evaluator is with the animals in the pen or if they are only seen from the outside. Normally animals are calm and relaxed unless there is something disturbing them, such as a person that gets into the pen (evaluator, worker), cows in heat, coming from/to the milking parlour, and distribution of food. All these factors might trigger agitation or aggression among herdmates and might influence the ‘general picture’ that the evaluator gets from the herd.

2.2.2. Relationships between animal-based welfare measurements

Spearman correlations (r) were used to investigate the relationship between 30 of the collected variables (Table 8).

Dirty lower legs (DLL) are correlated with dirty hindquarter (DHQ; r_s=0.73, P≤0.01) and with dirty udder (DU; r_s=0.83, P≤0.001). Also, DHQ and DU are highly correlated (r_s=0.86, P≤0.001; Figure 14). Other studies have obtained analogous results (Schreiner & Ruegg, 2003; Zurbrigg et al., 2005; Popescu, 2013). This suggests that the dirtiness classification of only one of these areas could be sufficient to determine animal dirtiness.

There is a positive correlation between lesions in the hindquarter (LHQ) and udder (LU; r_s=0.65, P≤0.05) and hairless patches in the same areas (r_s=0.71, P≤0.05).

There is a positive correlation between dirtiness and hairless patches in the lower back legs (r_s=0.67, P≤0.05) hindquarter (r_s=0.70, P≤0.05) and in the udder (r_s=0.73, P≤0.01), which can be explained by the fact that when dirt solidifies it gets highly attached to the hair coat, consequently when dirt falls, hair falls with it (Figure 8). Lesions and dirtiness are also positively correlated (DLL and LLBL r_s=0.67, P≤0.05; DHQ and LHQ r_s=0.60, P≤0.05; DU and LU r_s=0.59, P≤0.05). The finding that dirtier cows have higher probabilities of having lesions is in agreement with previous findings (Regula et al., 2004; Zurbrigg et al., 2005), but contrary to other (Potterson et al., 2011). Hairless patches and lesions are positively correlated on the hindquarter (HPHQ and LHQ; r_s=0.84, P≤0.001), lower back legs (HPLBL and LLBL; r_s=0.83, P≤0.001) and udder (HPU and LU; r_s=0.64, P≤0.05).

Percentage of cows colliding against the cubicles while lying (LC) is positively correlated with the presence of swelling in the hindquarter (SHQ; r_s=0.60, P≤0.05) and swelling (SNB; r_s=0.62, P≤0.1) and lesion (LNB; r_s=0.76, P≤0.01) in the neck/back area (Figures 9 and 10).

A positive correlation was also found between the percentage of cows lying outside (LO) and presence of hairless patches (HPHQ; r_s=0.61, P≤0.05) and lesions (LHQ; r_s=0.63, P≤0.05) in the hindquarter, lesions (LLBL; r_s=0.58, P≤0.05) and swellings (SLBL; r_s=0.51, P≤0.1) in the lower back legs, moderate lameness (ModL; r_s=0.58, P≤0.05) and severe lameness (SevL; r_s=0.61, P≤0.05). All these correlations confirm that changes in body size of Holstein–Friesian alters their necessities in terms of environment and that if these requirements are not achieved, it leads to welfare problems such as presence of integument alterations. Presence of cows lying outside (LO) is related with dirtiness in the lower back legs (DLL; r_s=0.71, P≤0.05). Similar findings were obtained in a study of Popescu et al. (2013).

Moderate (ModL) and severe lameness (SevL) are significantly correlated (r_s=0.71, P≤0.05). Moderate lameness (ModL) is positively correlated with presence of swelling in the neck/back area (SNB; r_s=0.70, P≤0.05) while severe lameness (SevL) is correlated with hairless patch on the lower back leg (HPLBL; r_s=0.66, P≤0.05) and lesion on the lower back leg (LLBL; r_s=0.68, P≤0.05). It is interesting to notice that severe lameness (SevL) is also significantly correlated with mortality (Mort; r_s=0.52, P≤0.1).

Presence of lesions in the udder (LU) is correlated with mastitis (Mast; r_s=0.66, P≤0.05) and presence of swelling in the udder (SU) is correlated with percentage of lean cows (Lean; r_s=0.76, P≤0.01).

2.2.3. Principles and criteria that contribute the most to the final welfare scores of Portuguese dairy farms (Multiple Correspondence Analysis)

A multiple correspondence analysis (MCA) was performed to understand which principles (Figure 15) and which criteria (Figure 16) are more related with the final scores attributed to each farm. To calculate the MCA of the principle scores, all the 24 farms were used. On the other hand, to calculate criterion scores, only 23 farms were used, since the other farm did not have results on ‘Absence of pain induced by management procedures’.

Looking at Figure 15 it is possible to see that ‘appropriate behaviour’ (Behav) is the principle that mostly defines whether the farm is scored as good (BehavAc is the closest to Good) or poor (BehavB is the closest to Poor). Acceptable ‘good feeding’ is another principle important to define ‘Good’ farms.

When looking at Figure 16, bad QBA (QBAB), bad ‘absence of pain induced by management procedures’ (HornB) and acceptable ‘absence of prolonged thirst’ (ThirstAc) are important factors on determining farms with poor welfare, since these are the closest to ‘Poor’. On the other hand, farms with good welfare are mostly defined by good QBA (QBAG), good ‘absence of pain induced by management procedures’ (HornAc) and good ‘comfort around resting’ (ComfortG).

The two MCAs combined together show that the ‘appropriate behaviour’ is the most determinant principle to classify farms with poor and good welfare, and that the QBA is the criteria within ‘appropriate behaviour’ that has the weight to determine that.

The QBA might seem subjective, since the purpose is to classify cows’ behaviour with adjectives that are normally associated with humans’ behaviour. However, as was stated before in this dissertation, studies have shown that this is a reliable method. Some adjectives are very easy to score, as ‘active’, ‘agitated’, ‘fearful’, ‘relaxed’, ‘calm’, ‘indifferent’, ‘apathetic’, ‘lively’, ‘inquisitive’, ‘irritable’, ‘uneasy’ and ‘distressed’. However, ‘calm’ and ‘relaxed’ or ‘irritable’ and ‘uneasy’ might be difficult to differentiate, since they are nearly synonyms.

Other adjectives such as ‘content’, ‘happy’, ‘frustrated’, ‘bored’, ‘positively occupied’, ‘friendly’, ‘sociable’ and ‘playful’ are more difficult to score. For example, ‘friendly’ or ‘sociable’ may be seen in an anthropomorphic point of view. If a herd is seen to have a social interaction such as liking each other (allo-grooming) in a repeated way, the observer would see it as a ‘friendly’ way of interacting, however its purpose is not well defined, and there are authors that see it as a way of establishing social hierarchy (Sato et al., 1991). ‘Playful’ is also difficult to interpret, since adult cattle do not play as much as calves, and if they do, it is not as obvious. And once again, a behaviour that can be associated with the establishment of hierarchy as soft head butting against other herdmate can sometimes be interpreted as playing, when there is not any obvious interest that could cause competition. The presence of a cow in heat that shows excitement and approaches easily to people might also seem fond of playing, when it is just acting in agreement to its physiological state.

As a conclusion, this might be the best way there is yet of measuring emotional state in animals, but other measures present in the WQ protocol, as absence of disease or comfort around resting, seem more reliable and more closely related to welfare.

2.2.4. National cattle database's potential welfare indicators

2.2.4.1. Results on the 24 dairy farms evaluated

The potential welfare indicators that corresponded to the expected values were proportion of calving intervals lower than the biological (345 days; CI<345), calf mortality (until six months; MtC), proportion of on-farm deaths (OFD), total life span (TLS), proportion of cows slaughtered at 30 days post partum (30ppSl), proportion of cows slaughtered at 60 days post partum (60ppSl), proportion of total carcass rejection (Trep) and female/male births ratio (FM). The others, namely age at first calving (AFC), proportion of calving intervals higher than 430 days (CI>430), mortality rate (Mt), proportion of emergency slaughter (EmgSl), proportion of partial carcass rejection (Prep), proportion of carcasses with less than 272 kg (C<272) and proportion of carcasses with fat class 'very thin' (class 1; VTC), did not correspond. OFD and FM were the only indicators significantly different between good and poor farms (Table 9).

a) Age at first calving

AFC was similar between good and poor welfare farms, with an average of 25 months. AFC between 23 and 24.5 months is the most profitable range (Ettema & Santos, 2004) therefore the average AFC for the evaluated farms is very close to the goal.

b) Calving intervals

CI<345 was 12% on poor and 10% on good welfare farms. This indicator was done to seek for register errors, since 345 days is the minimum possible for a cow's calving interval. These results could be the confirmation that farms with poor welfare have normally less organizational skills and commit more errors when registering their farm events. However, these values are not significantly different, so there may be no real detectable difference.

CI>430 (calving interval higher than 430 divided by total of calving intervals) was close to 45% in both good and poor farms. This value is extremely high, since according to Hartigan (1995), the percentage of cows in a herd outside the range of 365 and 415 days of calving interval should be less than 5%. Values outside this range will possibly mean lower production benefits for the farmer and might suggest presence of diseases or stress that resulted in reproductive failure. Also, high percentages of CI>430 might be related with factors not directly related to welfare, such as lack of oestrus detection or ineffective artificial insemination strategies.

A calving interval of 12 months can only be obtained by breading at the peak of production, which is a challenging time for the cow where the occurrence of metabolic diseases is more likely. Moreover, fertility problems increase with milk production, which will lead to difficulties in achieving the ideal calving interval (Gröhn, 1994; reviewed by Österman, 2003). Contrarily to the majority of the research, some studies have shown that higher calving intervals might be sometimes advantageous, namely in high yielding cows (Arbel et al., 2001; Österman, 2003). Actually, Ratnayake (1998) has shown that reproduction might be positively influenced with an increased calving interval (i.e. 549 days).

Therefore, the calving interval is a complex indicator that needs further investigation so that more accurate conclusions can be taken in relation to cows' welfare.

c) Mortality

The mortality of calves (MtC) was higher in poor (0.00097 deaths per animal-days) than in good welfare farms (0.00072 deaths per animal-days). Yet, it is possible that a farm that has optimal conditions within the groups of adult cows, has absolutely terrible conditions on the group of calves, and in this dissertation only adult cows were assessed. Moreover, as seen earlier in this dissertation, the mortality of adult cows was lower in farms considered having poor welfare and higher in good welfare farms. High mortality is an important indicator of welfare problems but the numbers should be analyzed with caution and always in connection with the culling data. An higher on-farm killing (high mortality) with low culling rates may show that sick animals are not transported or kept in suffering for long and are euthanized promptly.

Mt was a little higher in good farms (0.00013 deaths per animal-days) than in poor (0.00010 deaths per animal-days). These results are in accordance with what was obtained on mortality through the questioner to the farmers in the WQ protocol. However, mortality obtained by the questionnaire was related specifically to adult cows. It would be of great importance to compare the mortality obtained through the questionnaire to the farmer with the mortality obtained through the national database, however the dataset did not include animals' births before 2008 (unless they were slaughtered), therefore the age of those animals that were born before 2008 could not be calculated, and consequently mortality by ages was impossible to obtain.

OFD (on-farm deaths divided by the total of on-farm deaths, slaughtered animals and disappeared animals) was significantly different ($p \leq 0.01$) between both kinds of farms, with 55% of OFD for farms with good welfare and 85% for farms with poor welfare. From these results it is possible to conclude that there are more cows dying on-farm than being culled to the slaughterhouse. However, those cows that are sold to other farms before going to slaughterhouse are not being considered in this study, and that would give a more appropriate view of number of culled cows. In a study performed in Portugal, Barros (2013) concluded that within the totality of culled cows (n=2,476), 6% (n=156) were sold to other farms, 26% (n=641) died on-farm and 68% (n=1,679) were sold to the abattoir. But still, numbers of cows that died on-farm and that went to slaughter are quite different between the two studies.

Similarly to Mt, EmgSl was higher in good farms (1.44%) than in poor welfare farms (1.05%).

d) Total life span

TLS (date of slaughter minus date of birth) was higher for farms with good welfare (70 months) than for farms with poor welfare (67 months). Even with these results, longer life does not necessarily mean better welfare, since there are many factors that affect culling and some of those can lead to maintain diseased animals in the herd, which will influence their welfare negatively.

e) Post partum slaughter

The proportion of cows slaughtered at 30 days post partum (30ppSl; number of cows slaughtered after 0-30 days post partum divided by the number of slaughtered calved cows) was 20% and 8% for farms with poor welfare and for farms with good welfare, respectively. Similarly, 60ppSl was 14% and 26% for good and poor farms, in that order. Therefore it is possible to conclude that, generally, farms with poor welfare have higher culling rates for slaughter in the post partum than farms with good welfare. This is probably a sign of bad management (at calving, nutritional, bedding, prevention of diseases such as lameness or mastitis).

f) Carcass characteristics

Trep (number of totally rejected carcasses divided by number of approved carcasses, totally rejected carcasses and partially rejected organs or carcasses) was of 5% in good and 13% in farms with poor welfare. It could be a sign that when the welfare of animals is poor, economic losses are predicable, namely through the loss of carcass value, however, values between good and poor welfare farms are not significantly different. Prep, contrarily to Trep, was higher in good (2%) than in poor welfare farms (1%).

In regards to carcass weight and fat, carcasses of lower value were found in higher proportion in good farms than in poor welfare farms. But once again, these results are not significantly different.

g) Female/male births ratio

FM was calculated, similarly to IC<345, to understand if farms with poor welfare would perform more registration errors than farms with good welfare. Once again, it was possible to conclude that this hypothesis might be true, since the mean value for FM obtained for farms with poor welfare was 2, against a value of 1 to farms with good welfare, being statistically different between both kinds of farms.

2.2.4.2.The overall results from Portuguese dairy farms

The mean AFC was 27 months in the non evaluated farms, two months higher than the group of evaluated farms. Similarly, CI<345, CI>430, Mt, EmgSl, TLS, C<272 and VTC were lower on the evaluated farms than in the rest of dairy farms of the country. Contrarily to this, MtC, OFD, 30ppSl, 60ppSl and Trep had lower values for the non evaluated dairy farms than for the evaluated ones.

Calving earlier than the desired range (23 to 24.5 months; Ettema & Santos, 2004) might increase calving difficulty and reduce the liveability of calves, while calving at older ages does not bring advantages in yield, reproduction and health (reviewed by Pirlo et al., 2000; Ettema & Santos, 2004). Delayed puberty is normally caused by poor management (e.g. level of nutrition, high ambient temperatures, diseases, social environment; Hartigan, 1995) therefore Portuguese dairy farms should seek to reduce AFC by correcting bad management procedures so that they may obtain higher profit during the first lactation. Figure 2 shows the distribution of AFC in Portuguese dairy farms.

Similarly to the value of 45% of CI>430 on the evaluated farms, 48% is also a very high percentage of calving intervals out of the desired range. For national dairy farms, calving interval average is 450.5 days, with a SD of 135 days (Figure 3). When comparing with Sweden, for example, the average calving interval was 13.2 months (402.6 days; Österman, 2003).

The average percentage of CI<345 was 17%, which is probably related to errors in calving records. As a conclusion, record errors do happen and should be avoided since they alter the interpretation of age and events that occur during lifetime. Moreover, it reduces the level credibility of national databases.

National MtC average was 0.00057 deaths per animal-days. It only includes female calves, since some farmers have the incorrect habit of registering male calves only if they do not die in the first days of life. This record error is possible to confirm with the indicator FM. However it is possible that the same error occurs within female calves and the mortality results might be underestimated.

National average Mt was 0.00015 deaths per animal-days, higher than evaluated farms. Once again, it only includes females (of all ages).

OFD average was 41% with a high SD (30%). This percentage is high, since almost half of the cows from Portuguese dairy farms die on-farm and the other half goes to slaughter, however, as stated previously, movement to other farms is not included in this proportion. The distribution of on-farm deaths during lactation was produced (Figure 5) and, similarly to the results of Thomsen et al. (2004), the highest percentage of deaths occurred within the first 50 days of lactation. This might be related to the metabolic diseases typical from this period of lactation (e.g. hypocalcaemia) that may lead to downer cow syndrome, or it may be related to the worsening of diseases that were not treated before partum, such as locomotion disorders, which are one of the major causes for on-farm deaths.

EmgSl was 1.92%, therefore a higher average than in the farms evaluated (1.45% for good and 1.05% for poor welfare farms).

TLS national average was six years and nine months (81.28 months), however on-farm deaths were not included since the slaughter table included animals' age, but the movements table did not. Moreover, births before 2008 were not included in the dataset, therefore the age of those animals that died on-farm could not be calculated. In the study of Minchin et al. (2009), Holstein-Friesian had an average age at slaughter of eight years and two months (98 months), a difference of more than one year. Results of Barros (2013) from Portuguese farms were lower, with a mean culling age of five years and two months (62 months). Figure 4 shows the distribution of TLS among Portuguese dairy farms.

Similarly to the results of on-farm deaths and days after calving, percentage of slaughtered cows was also higher within the first 50 days post partum (Figure 6). This is in agreement with results of Sheldon et al. (2006) and Barros (2013).

Average C<272 and VTC were 61% and 47%, respectively, meaning that half of cows that are slaughtered were too thin. These results are similar to those of Minchin et al. (2009), in which more than 60% of dairy cows slaughtered failed to achieve three carcass parameters (fat class three or more; cold carcass weight 272 kg or more; conformation class P+ or more).

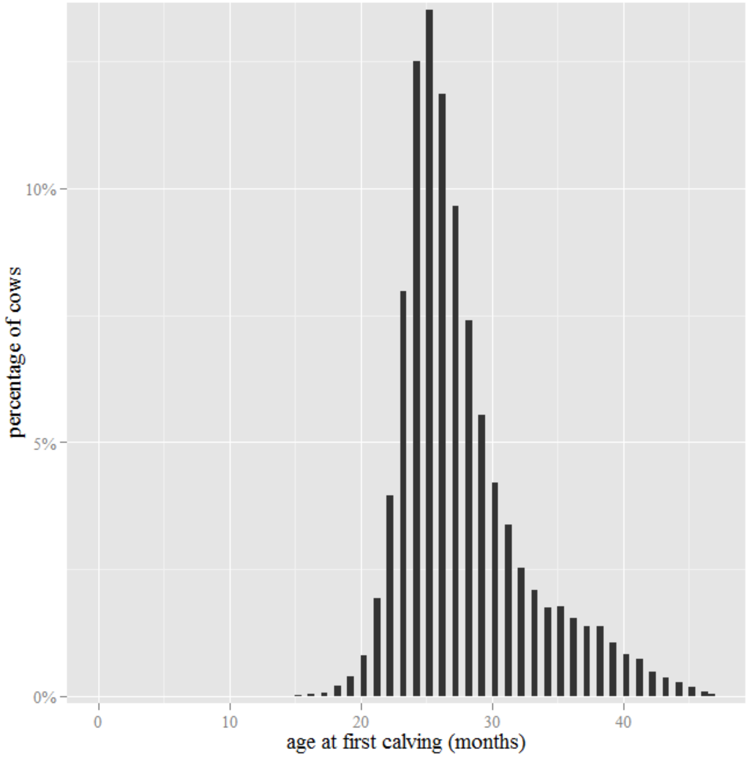

Figure 2 – Distribution of age at first calving (AFC; months) among Portuguese dairy cattle farms from 2008 until 2011.

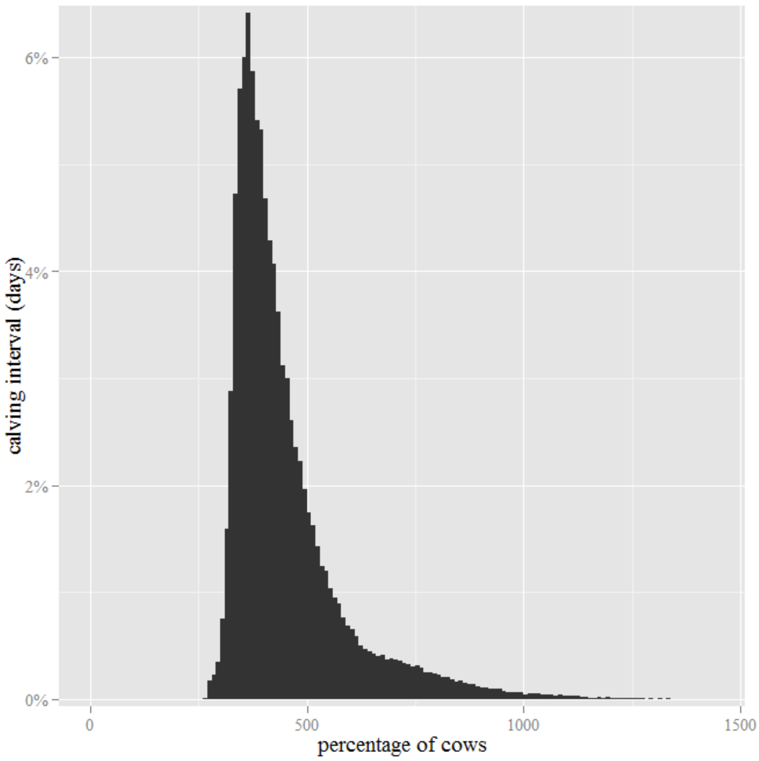

Figure 3 – Distribution of calving interval (CI; days) among Portuguese dairy cattle farms from 2008 until 2011.

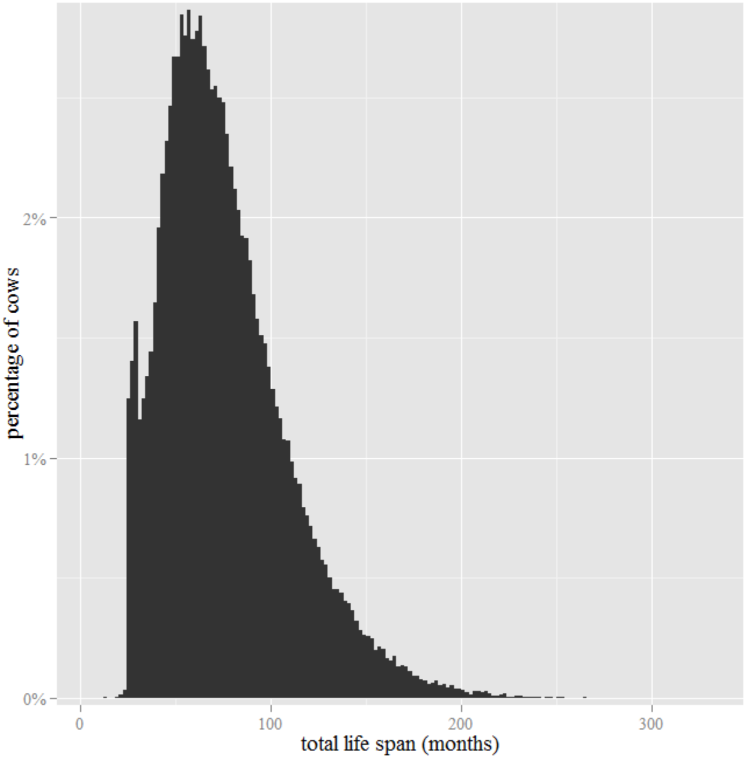

Figure 4 – Distribution of total life span (TLS; months) among Portuguese dairy cattle farms from 2008 until 2011.

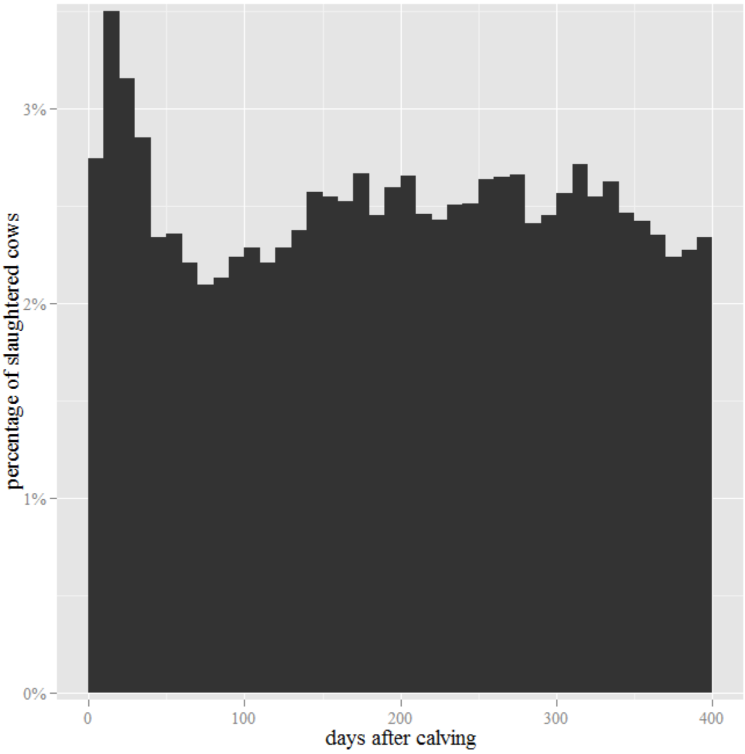

Figure 5 – Distribution of on-farm deaths in days after calving during the first 400 days of the lactation among Portuguese dairy cows from January 2008 until October 2012, all parities.

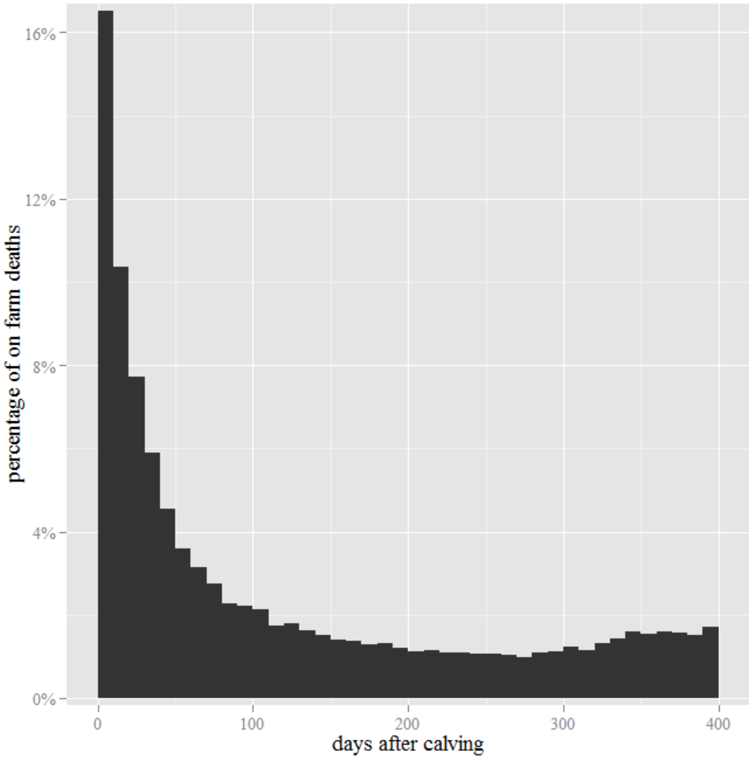

Figure 6 – Distribution of slaughtered cows in days after calving during the first 400 days of the lactation among Portuguese dairy cows from 2008 until 2011, all parities.

2.2.5. Associations between potential welfare indicators

Matrix correlation for potential welfare indicators is presented on Table 10.

Percentage of calving interval above 430 days (CI>430) and calving intervals lower than the biological (CI<345) were associated negatively (r_s=-0.59, P≤0.01). CI>430 were positively correlated with on-farm deaths (OFD; r_s=0.44, P≤0.05), mortality rate (Mt; r_s=0.58, P≤0.01), proportion of total carcass rejection (Trep; r_s=0.55, P≤0.01) and proportion of very thin carcasses (VTC; r_s=0.34, P≤0.1). These results show that those farms that have higher CI>430 have actually higher risks of having cows in bad condition than those farms that have calving intervals within the normal range. Other works have related higher risks of mortality with longer calving intervals (McConnel et al., 2008; Raboisson et al., 2011; Alvasen et al., 2012). These results are probably due to bad management or metabolic diseases because cows get too fat increasing the probability of dying after the next calving.

Proportion of cows slaughtered at 30 days post partum (30ppSl) and at 60 days post partum (60ppSl) were positively associated (r_s=0.64, P≤0.001). They were both associated with total carcass rejection (Trep). Research has already shown that there is a higher risk of culling in the post-partum period, especially in the first 60 days (Sheldon et al., 2006). Metabolic diseases, lameness and mastitis are some of the most important causes for this fact, therefore it is understandable that culling cows in this period is associated with some level of rejection.

Prep was related with VTC (r_s=0.58, P≤0.01). Trep was related with C<272 (r_s=0.35, P≤0.1) and with OFD (r_s=0.55, P≤0.01). VTC and C<272 were positively related, as expected (r_s=0.75, P≤0.001). Diseases that lead to partial rejection (e.g. mastitis, arthritis) might be associated with body condition loss, thus the association of Prep with VTC is understandable, as is the association between Trep and C<272. Moreover, cachexia is actually a cause for total rejection, which links directly Trep and C<272. The association between Trep and OFD is also possible to explain since OFD is normally related with late stages of disease or to severe trauma.

Mt was positively related with OFD (r_s=0.35, P≤0.1) but negatively related with EmgSl (r_s=-0.50, P≤0.01). This is probably caused by the fact that there are just a few farms with EmgSl and normally high mortalities are due to OFD. OFD was positively related with C<272 (r_s=0.45, P≤0.05) and to female/male births ratio (FM; r_s=0.37, P≤0.1). As said earlier, OFD are related with late stages of disease and these are normally accompanied by body condition loss, explaining the relation between OFD and C<272. On the other hand, the fact that those farms that have higher OFD have also tendency to have higher FM ratio can mean that these farms that do not make the registration of male calves are farms less organized, with bad management, which can explain higher OFD since disease prevention might be less efficient, and animals might be less observed and therefore problems are detected too late.

2.2.6. Associations between animal-based welfare measurements and potential welfare indicators

Table 11 shows correlations between 11 animal-based welfare measurements (lying behaviour [LC; LD], percentage of lean cows [Lean], mastitis [Mast], lameness [ModL; SevL] and presence of swelling in some body regions [SHQ; SLBL; SLFL; SNB; SU] and potential welfare indicators.

No relevant associations were shown, with the exception of the positive correlation between emergency slaughter and moderate lameness (ModL; r_s=0.45, P≤0.05). These relations are comprehensible, since emergency slaughter is performed whenever cows are severely harmed and unfit to be transported for slaughter. High percentage of lame cows in a farm can be a sign of producers' negligence, lack of prevention and treatment of early stages of lameness, which makes it likelier that farms will have cows that are unfit for transport to the slaughterhouse, which we can confirm from this correlation.

2.2.7. Creating a model to detect farms with poor welfare within the national cattle database

In this study, the number of farms with poor and good welfare was very uneven (5 to 19) and the differences between them were not significant (Table 5, 6 and 9), therefore SMOTE was applied to balance the two classes (good and poor; Figures 17 and 18), which resulted in a total number of 29 farms, 19 with good welfare and ten with poor welfare.

After using SMOTE, Classifier J48 from WEKA was used to create a model to detect farms with poor welfare (Figure 7). This model had an accuracy of 75.86%, correctly classifying 22 farms and classifying seven farms erroneously (Table 3). Therefore it is possible to say that it is a good model.

It is possible to see in Figure 7 that this tree has only two potential welfare indicators (OFD and CI>430), because it uses a method of 'pruning' to produce simple and accurate decision trees.

Even with such good level of accuracy, there are some ideas that should be discussed:

1) In this study, the sample size is much reduced when compared to the total number of farms in Portugal and it was not chosen randomly, therefore it cannot be said to be representative.
2) Farms considered 'good' were mainly 'acceptable' ("the welfare of animals is above or meets minimal requirements") according to the rules of the WQ protocol, therefore is does not correspond to the best scores of the WQ protocol ('excellent' and 'enhanced') in which the welfare of animals is of the highest level (WQ, 2009). That leads to the creation of a model that is associating farms with two levels of welfare that are not significantly different from each other and based on a dataset that is uneven (five farms with classification 'poor'/'bad' ['not classified' according to the WQ protocol] and 19 farms with classification 'good' [one farm 'enhanced' and 18 farms 'acceptable' according to the rules of the WQ protocol]). Instead of creating a model that actually detects farms with poor welfare, a model has been created that detects farms with 'very poor' welfare from a set of farms with poor ('acceptable') and very poor ('not classified') welfare, according to the WQ protocol. However, this could be useful for welfare inspectors since it selects the farms that need urgent correction, those with worst welfare.
3) The model created uses the national welfare indicator OFD, which was statistically different between farms with good and poor welfare (Table 9) and it considered that farms with a percentage of OFD lower or equal to 76% are farms with good welfare

and the others are farms with poor; however, it also uses the indicator CI>430 (not statistically different between the two classes) and it considered that farms with percentages of CI>430 higher than 48% are good farms, which is the contrary of what is generally accepted.

Therefore, it is possible to state that, in fact, it is possible to create a model to detect farms with poor welfare, however care must be taken with the dataset used. To create an accurate model that actually detects those farms with higher chances of having poor welfare, it is necessary to make an exhaustive WQ evaluation on a representative and randomly chosen number of national farms and then use the adequate method to create our final model to detect farms with poor welfare. J48 is an option, but there are other classifiers that can be better for larger datasets, such as the classifier 'Random Forest' (Ali, 2012).

This study was performed in dairy cattle, however it is a study method that can be applied to any kind of animal production system that has such a powerful national database as the national cattle database.

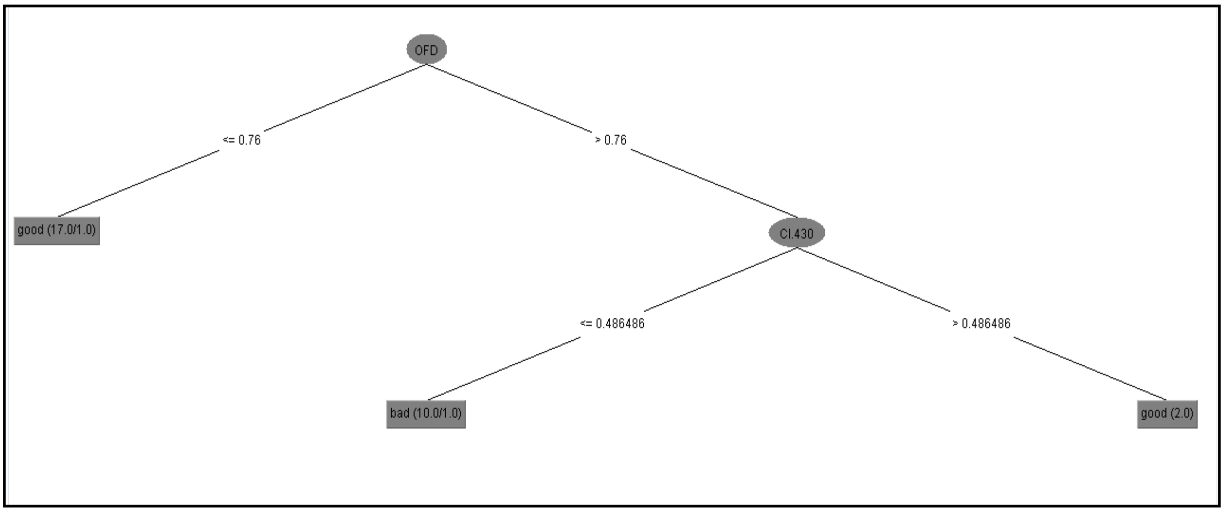

Figure 7 – Classification tree created with J48 classifier from Waikato Environment for Knowledge Analysis (WEKA) to detect farms with poor welfare.
Key to acronyms: bad, farms with 'poor' welfare, CI>430, Proportion of calving intervals higher than 430 days, good, farms with good welfare, OFD, Proportion of on-farm deaths.

Accuracy*: 75.86%			
	Predicted positive	Predicted negative	Class sensitivity**
Actual positive	7	3	0.7
Actual negative	4	15	0.789
Class precision***	0.63	0.833	

Table 3 – Contingency table in the classifier J48 from Waikato Environment for Knowledge Analysis (WEKA) to detect farms with poor welfare.

* Accuracy is a ratio of no. of correctly classified instances divided by the total no. of instances; therefore, this model has an accuracy of (22 / 29) = 0,76

** Sensitivity is a ratio of ((no. of true positive) / ((no. of true positive) + no. of false negative); therefore, for classifying a farm as having poor welfare, the created model has a sensitivity of (7 / (7 + 3)) = 0.7

*** Precision is a ratio of ((no. of true positive) / ((no. of true positive) + no. of false positive); therefore, for classifying a farm as having poor welfare, the created model has a precision of (7 / (7 + 4)) = 0.63 (Kumar & Rathee, 2011).

CHAPTER III – Conclusions

It is possible to create a model to detect farms with higher chances of having poor welfare. However, a representative number of dairy farms should be evaluated so that a reliable and accurate model can be created for nationwide use.

The WQ protocol:

- Within the 24 dairy farms evaluated with the WQ protocol, none was scored as excellent, one was scored as enhanced, 18 were acceptable and five were 'not classified'. Therefore it is possible to affirm that the majority of farms evaluated had minimal requirements of welfare and 21% of the farms were unacceptable in terms of welfare.
- The QBA was the criteria that had the most influence on whether a farm was classified as good or poor in terms of welfare.
- The main problems in Portuguese farms were associated with the criteria (1) 'absence of injuries' (15.63 average score from a 0 to 100 scale), (2) 'absence of pain induced by management procedures' (26.61 average score), (3) 'expression of other behaviours' (1.19 average score), (4) 'absence of prolonged thirst' (32.12 average score) and (5) 'comfort around resting' (28.40 average score).
- Integument alterations were the main factor for the low scores on 'absence of injuries', since the average percentage of cows presenting severe integument alterations (lesions and swellings; YSA) was more than 65% in both good and poor welfare farms. These integument alterations were mostly present on the lower back legs (LLBL; average of 42% of lesions in good farms, 38% in poor welfare farms) and on the neck/back region (SNB; average 15% swellings in good, 36% in poor farms). Moderate lameness was also high, with percentages on both good and poor farms around 40%. Severe lameness was lower, with average values between 10% and 14%.
- Bad results on 'absence of pain induced by management procedures' were caused by the absence of anaesthetics or analgesics to reduce the pain caused by disbudding, since only two farms of the 23 that answered to the questionnaire used those drugs. Moreover, two farms performed tail docking regularly on their calves.
- 'Expression of other behaviours' scored the lowest value, since only one of the 23 producers that answered to the questionnaire allowed their cows to graze.
- 'Absence of prolonged thirst' obtained a low average score because nine farms had an insufficient number of drinkers and other nine farms had dirty drinkers or only partly sufficient troughs to the number of cows in each pen.

- ‘Comfort around resting’ depends on cows’ cleanliness and lying behaviour. Good farms had generally dirtier cows than farms with poor welfare. The udder (DU) and the hindquarter (DHQ) were a ‘serious problem’ (more than 19% of cows dirty on these regions) in 20 and 18 farms, respectively. The percentage of cows lying outside the stall (LO) was a serious problem (more than 5%) in 11 farms, and nine of these were located in the north of Portugal.
- Percentage of cows colliding against the cubicles (LC) was significantly correlated with percentage of animals presenting swelling in the hindquarter (SHQ) and neck/back (SNB) area and lesions on the neck/back area (LNB). Moderate lameness (ModL) was positively related with swelling in the neck/back area (SNB) while severe lameness (SevL) was correlated with lesion on the lower back leg (LLBL). Mortality was associated with severe lameness. Mastitis (Mast) and lesions on the udder were also positively correlated.

National welfare indicators:

- On-farm deaths (OFD) was one of the two potential welfare indicators significantly different between farms with good and poor welfare, with 55% and 85%, respectively. Both OFD and culling for slaughter peaked within the first 50 days after calving. Mortality (Mt) was higher in good than in poor farms.
- Female-male births ratio was also significantly different between good and poor welfare farms, possibly being a sign of higher number of register errors in poor welfare farms.
- Proportion of calving intervals higher than 430 days (CI>430) was positively associated with OFD, Mt and poor carcass characteristics.

In conclusion, the welfare of Portuguese dairy farms is generally acceptable, meeting minimal requirements. In order to improve it, cubicles should be altered (number, bedding, dimensions), pain management should be applied in disbudded calves, more attention should be paid to cleanliness (drinkers and pen) and to the number of drinkers per pen.

The national cattle database analysis is a good alternative in the dairy welfare evaluation and it could be useful in helping official veterinary services of any country in detecting farms with higher risk of having poor welfare. This approach could be used in production systems of several animal species.

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Annex 1 – Tables

Table	Variable 1	Variable 2	Variable 3	Variable 4	Variable 5	Variable 6	Variable 7	Variable 8	Variable 9	Variable 10	Number of records
Live cattle	breed code	present farm	birth farm	animal id number	Sex	-	-	-	-	-	2,025,443
Births	breed code	farm code	animal id number	sex	mother id	father id	birth date	-	-	-	2,297,177
Movements	animal id number	movement type	farm code	entrance date	exit date	-	-	-	-	-	7,620,867
Slaughter	slaughter type	slaughter date	animal id number	age	Sex	weight	approval / rejection	carcass type	fat class	conformation class	2,615,076

Table 4 – Tables and respective variables included in the data subset extracted from National Database of Cattle Register and Identification (*Sistema Nacional de Identificação e Registo de Bovinos [SNIRB]*) at the end of 2012.

Calculated variable	Source tables	Selection parameters	Formula	Number of records
Age at first calving (AFC)	Live cattle, Births.	Calved cows; births between Jan. 2008 and Sep. 2010; calves between May 2009 and Dec. 2011.	Date at first calving minus date of birth (months); median per farm.	61,663 animals 5,947 farms
Proportion of calving intervals lower than 345 (CI<345) and higher than 430 days (CI>430)	Births	Calved cows; births between Jan. 2008 and Dec. 2011.	Difference between two successive parities (days); number of calving intervals lower than 345 / total number of calving intervals; number of calving intervals higher than 430 / total number of calving intervals.	222,662 calving intervals
Mortality rate until six months (MtC)	Births, Movements, Slaughter	Female calves; births between Jun. 2010 and May 2011; deaths between Jun. 2010 and Nov. 2011.	Number of on-farm deaths and emergency slaughter / animal-days*	28,736 animals 4,387 farms
Mortality rate (Mt)	Live cattle, Movements, Slaughter	Female cattle, 2011.	Number of on-farm deaths and emergency slaughter / animal-days*	388,687 animals 6,197 farms
Proportion of on-farm deaths (OFD)	Movements	Deaths between Jan. 2008 and Oct. 2012.	Number of on-farm deaths (9) / number of slaughtered animals (4), on-farm deaths (9) and animal disappearance (11)	6,340 farms
Proportion of emergency slaughter (EmgSl)	Slaughter	Calved cows; slaughter between Jan. 2007 and Jan. 2013.	Number of emergency slaughter / number of regular and emergency slaughters	6,285 farms
Total life span (TLS)	Live cattle, Slaughter	Calved cows; slaughter between Jan. 2007 and Jan. 2013.	Date of slaughter minus date of birth (months); median per farm.	110,573 animals 6,289 farms
Proportion of cows slaughtered at 30 (30ppSl) and 60 days (60ppSl) post partum	Births, Slaughter	Calved cows; from Jan. 2008 to Dec. 2011.	Date of slaughter minus date of last calving (days); number of cows slaughtered after 0-30 days post partum / number of slaughtered calved cows; number of cows slaughtered after 0-60 days post partum / number of slaughtered calved cows.	52873 animals 5,647 farms

Table 5 – Source tables, selection parameters, formula and sample size of the potential welfare indicators.

*animal-days: number of animals that were on farm during that period of time (6months vs. 12months) multiplied by number of days on farm (180 vs. 365) plus sum of the number of days that the animals that left the farm (transfer in life [3], slaughter [4], depart to EU [7], exportation [8], death on farm [9], disappearance [11], deactivation [20]) spent there

Proportion of partial (Prep) and total (Trep) carcass rejection	Live cattle, Slaughter	Calved cows; slaughter between Jan. 2007 and Jan. 2013.	Number of partially rejected carcasses (D) / number of approved carcasses (A), totally rejected carcasses (T) and partially rejected organs or carcasses (D); Number of totally rejected carcasses (T) / number of approved carcasses (A), totally rejected carcasses (T) and partially rejected organs or carcasses (D).	6288 farms
Proportion of carcasses with less than 272 kg (C<272)	Slaughter	Calved cows; slaughter between Jan. 2007 and Jan. 2013.	Number of carcass with less than 272kg / number of slaughtered calved cows.	124,616 animals 6,289 farms
Proportion of carcasses with fat class ‘very thin’ (class 1; VTC)	Slaughter	Calved cows; slaughter between Jan. 2007 and Jan. 2013.	Number of carcasses with fat class 1 / number of carcasses with fat class 1 (very thin) or 3 (normal).	5912 farms
Female/male birth ratio	Births	Births between Jun. 2010 and May 2011.	Number of female calves / number of male calves.	4919 farms

Table 5 – Source tables, selection parameters, formula and sample size of the potential welfare indicators. (continuation)

Principles	Measures	Welfare				*P*
		good		poor		
		Mean	SD	Mean	SD	
Good feeding	Lean (%)	1.83	2.20	2.30	3.00	n.s.
Good housing	DHQ (%)	50.48	30.02	24.73	12.28	**
	DLL (%)	32.32	25.16	16.99	9.48	*
	DU (%)	59.04	28.21	36.93	16.52	*
	LC (%)	19.74	23.65	34.04	13.53	n.s.
	LD (secs)	5.24	2.16	4.93	1.15	n.s.
	LO (%)	10.08	12.18	8.66	9.19	n.s.
Good health	ModL (%)	37.70	14.55	43.92	15.82	n.s.
	SevL (%)	10.92	6.77	13.60	15.26	n.s.
	NIA (%)	2.92	4.41	1.06	0.99	n.s.
	YMA (%)	27.87	13.15	22.65	12.62	n.s.
	YSA (%)	69.21	14.54	76.29	12.72	n.s.
	Vulv (%)	1.49	1.71	2.14	2.98	n.s.
	Ocu (%)	0.31	0.63	0.80	0.74	n.s.
	Nas (%)	13.24	9.63	13.55	9.85	n.s.
	Cough (average/cow/15min)	0.13	0.09	0.11	0.02	n.s.
	Diar (%)	2.67	2.57	1.38	2.20	n.s.
	Hamp (%)	0.14	0.63	0.00	0.00	n.s.
	Mast (%)	14.02	7.17	19.98	24.44	n.s.
	Mort (%)	10.15	4.07	9.67	2.90	n.s.
	Dist (%)	2.69	1.50	4.17	2.70	n.s.
	Down (%)	4.62	3.43	2.74	1.67	n.s.
Appropriate behaviour	DP (average/cow/h)	0.46	0.32	0.63	0.50	n.s.
	HB (average/cow/h)	0.39	0.29	0.36	0.12	n.s.
	AD0 (%)	37.17	15.67	31.16	15.43	n.s.
	AD050 (%)	37.05	8.16	37.53	4.08	n.s.
	AD50100 (%)	8.42	5.10	11.89	2.81	n.s.
	AD100 (%)	17.36	9.54	19.42	13.41	n.s.

Table 6 – Independent samples T-tests between farms with good and poor welfare on several WQ protocol's measures collected in 24 Portuguese dairy farms.

Key to acronyms: AD0, percentage of cows that can be touched, AD050, percentage of cows with avoidance distance between 0 and 50 cm, AD100, percentage of cows with avoidance distance higher than 100 cm, AD50100, percentage of cows with avoidance distance between 50 and 100 cm, DHQ, percentage of cows with dirty hindquarter, Diar, percentage of cows with diarrhoea, Dist, percentage of cows with dystocia on the last 12 months before evaluation, DLL, percentage of cows with dirty lower legs, Down, percentage of downer cows on the last 12 months before evaluation, DP, average displacements per cow per hour, DU, percentage of cows with dirty udder, Hamp, percentage of cows with hampered respiration, HB, average head butts per cow per hour, LC, percentage of cows that collide while lying, LD, time to lie down, Lean, percentage of lean cows, LO, percentage of cows lying outside, Mast, percentage of cows with mastitis during the three months before evaluation, ModL, percentage of cows with moderate lameness, Mort, percentage of cows that have died during the 12 months before evaluation, Nas, percentage of cows with nasal discharge, NIA, percentage of cows without integument alterations, Ocu, percentage of cows with ocular discharge, SevL, percentage of cows with severe lameness, Vulv, percentage of cows with vulvar discharge, YMA, percentage of cows with moderate integument alterations, YSA, percentage of cows with severe integument alterations. n.s.: Not significant; * $p<0.05$; ** $p<0.01$; *** $p<0.001$.

Measures	Welfare				*P*
	Good		poor		
	Mean	SD	Mean	SD	
HPLFL	49.67	27.63	66.30	4.82	*
LLFL	15.63	13.75	17.01	5.75	n.s.
SLFL	6.50	5.06	9.39	2.76	n.s.
HPNB	19.10	14.46	41.08	28.88	n.s.
LNB	2.91	1.95	5.23	5.28	n.s.
SNB	14.79	12.62	35.84	27.46	n.s.
HPHQ	44.17	19.20	55.79	12.33	n.s.
LHQ	20.23	11.82	26.01	10.01	n.s.
SHQ	6.44	4.57	8.46	4.69	n.s.
HPLBL	84.45	16.47	86.66	16.28	n.s.
LLBL	42.09	17.59	37.60	21.06	n.s.
SLBL	14.81	11.90	15.99	11.42	n.s.
HPU	24.21	14.53	24.76	8.39	n.s.
LU	5.17	6.41	3.57	1.71	n.s.
SU	1.17	1.46	2.34	1.88	n.s.

Table 7 – T-tests between farms with good and poor welfare on integument alterations (hairless patches, lesions, and swellings) in different body regions (lower front legs, neck/back region, hindquarter, lower back leg and udder).

Key to acronyms: HPHQ, percentage of cows with hairless patch on the hindquarter, HPLBL percentage of cows with hairless patch on the lower back leg, HPLFL, percentage of cows with hairless patch on the lower front leg, HPNB, percentage of cows with hairless patch on the neck/back, HPU, percentage of cows with hairless patch on the udder, LHQ, percentage of cows with lesion on the hindquarter, LLBL, percentage of cows with lesion on lower back leg, LLFL, percentage of cows with lesion on the lower front leg, LNB, percentage of cows with lesion on the neck/back, LU, percentage of cows with lesion on the udder, SHQ, percentage of cows with swelling on the hindquarter, SLBL, percentage of cows with swelling on the lower back leg, SLFL, percentage of cows with swelling on the lower front leg, SNB, percentage of cows with swelling on the neck/back, SU, percentage of cows with swelling on the udder. n.s.: Not significant; * $p<0.05$; ** $p<0.01$; *** $p<0.001$.

	Cough	DHQ	Diar	DLL	DU	HPHQ	HPLBL	HPLFL	HPNB	HPU	LC	LD	Lean	LHQ	LLBL
Cough		0.13	-0.47	-0.01	-0.03	-0.13	-0.34	0.06	-0.33	0.15	-0.02	-0.12	0.17	0.15	-0.20
DHQ			-0.20	0.73	**0.86**	0.70	0.43	-0.48	-0.30	0.58	-0.05	0.09	-0.07	0.60	0.66
Diar				-0.04	-0.16	0.10	-0.04	0.06	-0.01	0.07	-0.12	0.32	*-0.52*	-0.06	-0.25
DLL					**0.83**	0.71	0.67	-0.16	-0.03	0.47	-0.30	0.07	-0.29	0.58	0.67
DU						0.70	0.46	-0.17	0.04	0.73	-0.41	-0.08	-0.11	*0.52*	0.71
HPHQ							0.34	0.01	0.20	0.71	-0.16	-0.12	0.15	**0.84**	*0.52*
HPLBL								-0.20	-0.22	0.00	-0.20	0.32	-0.49	0.32	**0.83**
HPLFL									0.38	0.20	-0.63	-0.26	0.15	-0.03	-0.06
HPNB										0.22	-0.05	-0.45	0.41	0.17	-0.22
HPU											*-0.51*	-0.18	0.04	0.66	0.38
LC												0.24	0.24	0.00	-0.39
LD													-0.73	0.01	0.20
Lean														0.07	-0.24
LHQ															0.45
LLBL															
LLFL															
LNB															
LO															
LU															
Mast															
ModL															
Mort															
Nas															
SevL															
SHQ															
SLBL															
SLFL															
SNB															
SU															
Vulv															

Table 8 – Matrix of spearman rank correlations between several variables of welfare collected on 24 Portuguese dairy farms.

	LLFL	LNB	LO	LU	Mast	ModL	Mort	Nas	SevL	SHQ	SLBL	SLFL	SNB	SU	Vulv
Cough	-0.13	-0.18	0.09	0.29	0.22	-0.13	-0.20	0.35	-0.20	0.43	0.28	-0.31	-0.02	0.01	-0.09
DHQ	-0.20	-0.10	0.49	0.66	0.08	0.31	0.29	-0.27	0.44	0.39	0.69	0.31	0.03	-0.04	0.18
Diar	0.26	-0.12	-0.43	-0.02	-0.09	-0.38	0.25	-0.29	-0.14	*-0.53*	-0.33	0.02	-0.35	-0.05	0.14
DLL	0.14	-0.40	*0.54*	*0.52*	0.05	-0.03	0.24	-0.43	0.31	0.15	0.41	0.44	-0.26	-0.20	-0.18
DU	0.25	-0.29	0.46	0.59	0.21	0.13	0.17	-0.10	0.22	0.11	0.45	0.41	-0.21	-0.19	-0.14
HPHQ	0.17	0.01	0.61	*0.55*	0.13	0.17	0.48	-0.35	0.35	0.24	0.42	0.18	-0.13	0.38	0.22
HPLBL	-0.12	-0.15	0.41	0.37	0.12	0.17	0.45	-0.58	0.66	0.06	0.25	0.34	-0.02	-0.49	-0.13
HPLFL	0.79	-0.09	-0.11	0.10	0.58	-0.50	-0.01	0.19	-0.34	-0.43	-0.59	*-0.55*	-0.65	0.14	-0.42
HPNB	0.49	0.24	0.12	-0.30	-0.05	-0.10	-0.13	0.32	-0.41	0.00	-0.14	0.34	0.08	0.32	-0.05
HPU	0.49	-0.16	0.35	0.64	0.41	-0.06	0.14	0.16	-0.05	0.03	0.34	0.08	-0.31	0.09	0.07
LC	-0.81	0.61	0.00	-0.33	-0.60	0.30	-0.10	-0.22	0.10	0.60	0.45	0.27	0.76	0.39	0.69
LD	-0.27	0.15	-0.17	0.37	0.17	-0.23	0.05	-0.70	0.27	0.11	0.32	0.06	0.02	-0.31	0.40
Lean	-0.08	0.29	0.32	-0.34	-0.15	0.46	-0.10	0.42	-0.05	0.29	-0.03	-0.25	0.32	0.76	0.08
LHQ	-0.03	0.22	0.63	0.65	0.17	0.10	0.40	-0.25	0.30	*0.52*	0.69	0.25	0.08	0.26	0.44
LLBL	0.03	-0.15	0.58	0.60	0.36	0.29	0.33	-0.44	0.68	0.07	0.36	0.13	-0.13	-0.29	-0.06
LLFL		-0.34	-0.19	0.16	*0.51*	*-0.56*	-0.03	0.27	-0.47	-0.59	*-0.54*	-0.15	-0.77	-0.10	*-0.56*
LNB			-0.15	0.07	0.00	0.07	0.18	-0.05	-0.02	0.47	0.32	0.13	0.45	0.34	0.65
LO				0.18	-0.06	0.58	0.07	-0.27	0.61	0.43	*0.51*	0.09	0.30	0.32	0.19
LU					0.66	-0.22	0.41	-0.29	0.23	0.27	0.50	-0.04	-0.35	-0.19	0.14
Mast						-0.24	0.38	0.03	0.10	0.00	-0.10	-0.48	-0.42	-0.18	-0.28
ModL							0.20	-0.01	0.71	0.36	0.29	-0.02	0.70	0.29	0.25
Mort								-0.29	*0.52*	0.20	0.03	-0.10	0.00	0.03	0.00
Nas									-0.59	-0.10	-0.24	-0.03	0.05	-0.07	-0.32
SevL										0.29	0.33	-0.13	0.35	0.05	0.22
SHQ											0.79	0.23	0.67	0.27	0.46
SLBL												0.47	*0.51*	0.04	0.63
SLFL													0.31	-0.33	0.16
SNB														0.21	*0.54*
SU															0.43
Vulv															

Table 8 - Matrix of spearman rank correlations between several variables of welfare collected on 24 Portuguese dairy farms. (continuation)

Key to acronyms: Cough, mean coughing per cow per 15 minutes, DHQ, percentage of cows with dirty hindquarter, Diar, percentage of cows with diarrhoea, DLL, percentage of cows with dirty lower legs, DU, percentage of cows with dirty udder, HPHQ, percentage of cows with hairless patch on the hindquarter, HPLBL percentage of cows with hairless patch on the lower back leg, HPLFL, percentage of cows with hairless patch on the lower front leg, HPNB, percentage of cows with hairless patch on the neck/back, HPU, percentage of cows with hairless patch on the udder, LC, percentage of cows that collide while lying, LD, time to lie down, Lean, percentage of lean cows, LHQ, percentage of cows with lesion on the hindquarter, LLBL, percentage of cows with lesion on the lower back leg, LLFL, percentage of cows with lesion on the lower front leg, LNB, percentage of cows with lesion on the neck/back, LO, percentage of cows lying outside, LU, percentage of cows with lesion on the udder, Mast, percentage of cows with mastitis during the three months before evaluation, ModL, percentage of cows with moderate lameness, Mort, percentage of cows that have died during the 12 months before evaluation, Nas, percentage of cows with nasal discharge, SevL, percentage of cows with severe lameness, SHQ, percentage of cows with swelling on the hindquarter, SLBL, percentage of cows with swelling on the lower back leg, SLFL, percentage of cows with swelling on the lower front leg, SNB, percentage of cows with swelling on the neck/back, SU, percentage of cows with swelling on the udder, Vulv, percentage of cows with vulvar discharge. *$P \leq 0.1$* (italicised coefficient), $P \leq 0.05$ (underline coefficient), $P \leq 0.01$ (double underline coefficient) or **$P \leq 0.001$** (bold coefficient).

Indicator	Dairy Farms						
	not evaluated		good		poor		*p* (#)
	Mean	SD	Mean	SD	Mean	SD	
AFC (months)	27.283	3.822	25.895	0.922	25.400	1.673	n.s.
CI<345 (%)	17.008	12.924	9.959	5.462	12.264	5.074	n.s.
CI>430 (%)	48.069	20.792	45.831	10.666	44.872	4.831	n.s.
MtC (deaths per animal-days)	5.70E-04	3.12E-03	7.20E-04	6.30E-04	9.70E-04	7.20E-04	n.s.
Mt (deaths per animal-days)	1.50E-04	1.97E-03	1.30E-04	9.00E-05	1.00E-04	7.00E-05	n.s.
OFD (%)	40.709	29.890	55.222	23.164	85.439	11.156	**
EmgSl (%)	1.923	6.614	1.445	1.752	1.053	2.354	n.s.
TLS (months)	81.282	29.274	69.711	12.167	67.300	7.799	n.s.
30ppSl (%)	6.128	13.605	7.899	8.456	20.339	44.538	n.s.
60ppSl (%)	10.905	18.026	13.676	10.132	26.274	41.600	n.s.
Prep (%)	1.221	4.838	1.651	1.779	0.638	1.173	n.s.
Trep (%)	4.018	9.403	5.136	3.314	13.278	20.553	n.s.
C<272 (%)	61.088	28.249	38.915	10.875	35.135	21.895	n.s.
VTC (%)	47.296	33.951	37.399	13.337	31.179	21.883	n.s.
FM	1.349	1.125	1.222	0.563	2.056	0.808	*

Table 9 – Results of potential welfare indicators from national cattle database on farms with good and poor welfare.
Key to acronyms: AFC, Age at first calving, C<272, Proportion of carcasses with less than 272 kg, CI<345, Proportion of calving intervals lower than the biological (345 days), CI>430, Proportion of calving intervals higher than 430 days, EmgSl, Proportion of emergency slaughter, FM, female/male births ratio, good, farms with good welfare, Mt, Mortality rate (obtained by national database), MtC, Calf mortality (until six months), OFD, Proportion of on-farm deaths, poor, farms with poor welfare, Prep, Proportion of partial carcass rejection, TLS, Total life span, Trep, Proportion of total carcass rejection, VTC, Proportion of carcasses with fat class 'very thin' (class 1), 30ppSl, Proportion of cows slaughtered at 30 days post partum, 60ppSl, Proportion of cows slaughtered at 60 days post partum. (#) Wilcoxon tests between farms with poor and good welfare. n.s.: Not significant; * p<0.05; ** *p*<0.01; *** *p*<0.001.

	C<272	CI<345	CI>430	EmgSl	FM	AFC	TLS	Mt	MtC	OFD	Prep	Trep	VTC	30ppSl	60ppSl
C<272		-0.18	0.31	-0.01	0.13	0.45	0.28	0.24	0.12	0.45	0.19	*0.35*	**0.75**	0.04	-0.14
CI<345			-0.59	0.00	-0.17	0.21	-0.33	-0.32	-0.09	-0.21	0.20	-0.10	0.02	0.14	0.12
CI>430				-0.34	0.22	0.10	0.26	0.58	0.03	0.44	0.17	0.55	*0.34*	0.14	0.16
EmgSl					-0.06	0.03	0.42	-0.50	0.32	-0.34	-0.01	-0.07	-0.28	-0.02	0.20
FM						-0.28	0.19	0.07	0.03	*0.37*	-0.24	0.24	-0.06	-0.22	-0.32
AFC							0.06	0.07	-0.19	-0.17	*0.34*	0.00	0.48	0.13	-0.04
TLS								0.11	0.27	0.11	0.25	0.06	0.18	-0.15	0.01
Mt									0.17	*0.35*	0.21	0.28	*0.37*	-0.05	0.03
MtC										0.14	0.01	0.04	-0.04	-0.22	0.06
OFD											-0.19	0.55	0.16	0.07	0.21
Prep												0.09	0.58	0.16	0.13
Trep													0.28	0.43	0.55
VTC														0.11	-0.15
30ppSl															**0.64**
60ppSl															

Table 10 – Matrix of spearman rank correlations between potential national welfare indicators on 24 Portuguese dairy farms.
Key to acronyms: C<272, Proportion of carcasses with less than 272 kg, CI<345, Proportion of calving intervals lower than the biological (345 days), CI>430, Proportion of calving intervals higher than 430 days, EmgSl, Proportion of emergency slaughter, FM, Female/male births ratio, AFC, Age at first calving, TLS, Total life span (months), Mt, Mortality rate (obtained by national database), MtC, Calf mortality (until six months), OFD, Proportion of on-farm deaths, Prep, Proportion of partial carcass rejection, Trep, Proportion of total carcass rejection, VTC, Proportion of carcasses with fat class 'very thin' (class 1), 30ppSl, Proportion of cows slaughtered at 30 days post partum, 60ppSl, Proportion of cows slaughtered at 60 days post partum. *P≤0.1* (italicised coefficient), P≤0.05 (underline coefficient), P≤0.01 (double underline coefficient) or ***P*≤0.001** (bold coefficient).

	C<272	CI<345	CI>430	EmgSl	FM	LC	LD	Lean	Mast	AFC	TLS	ModL	Mt
C<272		-0.18	0.31	-0.01	0.13	-0.07	0.12	-0.24	-0.31	0.45	0.28	-0.26	0.24
CI<345			**-0.59**	0.00	-0.17	-0.18	*-0.38*	-0.04	-0.06	0.21	-0.33	-0.02	-0.32
CI>430				-0.34	0.22	-0.14	0.33	-0.13	0.15	0.10	0.26	-0.19	0.58
EmgSl					-0.06	0.21	0.09	0.23	-0.28	0.03	0.42	0.45	-0.50
FM						0.25	-0.06	-0.25	-0.10	-0.28	0.19	0.03	0.07
LC							0.30	0.17	-0.27	-0.20	-0.20	0.45	-0.24
LD								-0.07	-0.03	-0.17	0.15	0.11	-0.12
Lean									0.19	-0.02	-0.05	0.28	-0.40
Mast										-0.30	0.05	0.01	0.28
AFC											0.06	-0.09	0.07
TLS												0.29	0.11
ModL													-0.23
Mt													
MtC													
OFD													
Prep													
SevL													
SHQ													
SLBL													
SLFL													
SNB													
SU													
Trep													
VTC													
30ppSl													
60ppSl													

Table 11 – Matrix of spearman rank correlations between several WQ protocol variables collected on 24 Portuguese dairy farms and potential national welfare indicators.

	MtC	OFD	Prep	SevL	SHQ	SLBL	SLFL	SNB	SU	Trep	VTC	30ppSl	60ppSl
C<272	0.12	0.45	0.19	-0.01	-0.07	-0.07	0.05	-0.20	-0.06	*0.35*	**0.75**	0.04	-0.14
CI<345	-0.09	-0.21	0.20	-0.26	*-0.39*	-0.15	-0.29	*-0.35*	-0.02	-0.10	0.02	0.14	0.12
CI>430	0.03	0.44	0.17	0.30	0.28	0.23	0.54	0.15	0.13	0.55	*0.34*	0.14	0.16
EmgSl	0.32	-0.34	-0.01	0.33	0.04	-0.08	-0.32	0.18	-0.30	-0.07	-0.28	-0.02	0.20
FM	0.03	*0.37*	-0.24	0.07	0.52	0.33	0.09	0.12	0.45	0.24	-0.06	-0.22	-0.32
LC	0.07	0.02	-0.48	0.06	0.48	*0.35*	0.22	0.50	0.08	-0.04	*-0.34*	-0.40	-0.07
LD	-0.26	0.25	-0.26	0.61	-0.06	0.17	0.08	0.06	-0.32	0.23	-0.08	0.12	0.29
Lean	0.28	-0.21	-0.06	0.14	0.07	-0.01	0.07	0.30	0.31	-0.05	-0.18	0.26	0.23
Mast	-0.02	-0.05	0.05	0.15	0.19	0.27	-0.09	-0.11	0.15	0.12	-0.08	0.21	0.08
AFC	-0.19	-0.17	*0.34*	-0.08	-0.15	-0.12	0.08	-0.13	0.02	0.00	0.48	0.13	-0.04
TLS	0.27	0.11	0.25	0.42	0.20	0.08	-0.12	0.31	-0.05	0.06	0.18	-0.15	0.01
ModL	0.39	-0.30	-0.15	0.53	0.51	0.42	0.03	**0.71**	-0.07	-0.29	-0.43	*-0.38*	-0.03
Mt	0.17	*0.35*	0.21	-0.11	0.33	0.20	0.26	0.04	0.05	0.28	*0.37*	-0.05	0.03
MtC		0.14	0.01	0.13	0.27	-0.01	0.01	*0.35*	-0.10	0.04	-0.04	-0.22	0.06
OFD			-0.19	0.16	-0.01	0.07	0.41	-0.12	0.18	0.55	0.16	0.07	0.21
Prep				-0.15	-0.19	-0.13	0.08	-0.07	0.11	0.09	0.58	0.16	0.13
SevL					0.14	*0.35*	0.12	0.19	-0.10	0.32	-0.26	0.13	*0.37*
SHQ						**0.62**	0.26	**0.63**	0.28	-0.02	-0.20	-0.33	-0.16
SLBL							0.49	*0.37*	0.20	0.17	-0.23	-0.32	-0.07
SLFL								0.34	0.27	0.30	-0.05	-0.17	0.14
SNB									0.13	-0.26	-0.19	-0.52	-0.13
SU										0.29	0.07	0.15	-0.05
Trep											0.28	0.43	0.55
VTC												0.11	-0.15
30ppSl													**0.64**
60ppSl													

Table 11 – Matrix of spearman rank correlations between several WQ protocol variables collected on 24 Portuguese dairy farms and potential national welfare indicators. (continuation)

Key to acronyms: C<272, Proportion of carcasses with less than 272 kg, CI<345, Proportion of calving intervals lower than the biological (345 days), CI>430, Proportion of calving intervals higher than 430 days, EmgSl, Proportion of emergency slaughter, FM, Female/male births ratio, LC, percentage of cows that collide while lying, LD, time to lie down, Lean, percentage of lean cows, Mast, percentage of cows with mastitis during the three months before evaluation, AFC, Age at first calving, TLS, Total life span (months), ModL, percentage of cows with moderate lameness, Mt, Mortality rate (obtained by national database), MtC, Calf mortality (until six months), OFD, Proportion of on-farm deaths, Prep, Proportion of partial carcass rejection, SevL, percentage of cows with severe lameness, SHQ, percentage of cows with swelling on the hindquarter, SLBL, percentage of cows with swelling on the lower back leg, SLFL, percentage of cows with swelling on the lower front leg, SNB, percentage of cows with swelling on the neck/back, SU, percentage of cows with swelling on the udder, Trep, Proportion of total carcass rejection, VTC, Proportion of carcasses with fat class ‘very thin’ (class 1), 30ppSl, Proportion of cows slaughtered at 30 days post partum, 60ppSl, Proportion of cows slaughtered at 60 days post partum. *P≤0.1* (italicised coefficient), P≤0.05 (underline coefficient), P≤0.01 (double underline coefficient) or ***P*≤0.001** (bold coefficient).

Annex 2 – Field data sheets

Qualitative Behaviour Assessment

Name: ____________________

Date: ____________________

Time: ____________________

Farm: ____________________

Housing Unit: ____________________

No. of animals: ____________________

Breed: ____________________

Active	Min		Max
Relaxed	Min		Max
Fearful	Min		Max
Agitated	Min		Max
Calm	Min		Max
Content	Min		Max
Indifferent	Min		Max
Frustrated	Min		Max
Friendly	Min		Max
Bored	Min		Max
Positively Occupied	Min		Max
Lively	Min		Max

Inquisitive	Min		Max
Irritable	Min		Max
Uneasy	Min		Max
Sociable	Min		Max
Apathetic	Min		Max
Happy	Min		Max
Distressed	Min		Max
Playful	Min		Max

General comments on observations:

Farm:______________________________ **In-Parlour Clinical Scoring Sheet** Date:______________________

Observer:______________________

	Udder								Lower Legs	Lower Back Leg				Disease (0,2)		
	Clean (0,2)	Hairless (count)	Lesions (count)	Hairless Lesion	Swellings (count)	Cow ID	Side of Cow (left/right)	Breed	Clean (0,2)	Hairless (count)	Lesions (count)	Hairless Lesion	Swellings (count)	Diarrhoea	Vulvar Discharge	Loco Score
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
13																
14																
15																
16																
17																
18																
19																
20																
21																
22																

Clean (lower legs) 0 = no dirt/minor splashing, 2 = separate or continuous plaques. Clean (udder) 0 = no dirt/minor splashing, other than on teats, 2 = distinct plaques on udder or any dirt on teats.

Hairless - area with hair loss, no skin damage, thinning of coat, possible hyperkeratosis. Lesion - scab/wound, dermatitis, completely/partly missing teat. Swelling - any swollen area.

Hairless patch with lesion - hair loss area with scab/wound within.

Farm:______________________________ **Other Clinical Scoring Sheet** Date:______________________

Observer:______________________

			Flank / Upper legs	Flank/Side			Lower Front Leg			Hindquarter			Neck/Back/Shoulder			(0,1,2)	Disease (0,2)		
	Cow ID	Side of Cow (left/right)	Clean (0,2)	Hairless Patches (count)	Lesions (count)	Swellings (count)	Hairless Patches (count)	Lesions (count)	Swellings (count)	Hairless Patches (count)	Lesions (count)	Swellings (count)	Hairless Patches (count)	Lesions (count)	Swellings (count)	Body Condition	Nasal Discharge	Ocular Discharge	Hampered Respiration
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
11																			
12																			
13																			
14																			
15																			
16																			
17																			
18																			
19																			
20																			
21																			
22																			

Clean - 0 = no dirt/minor splashing, 2 = separate or continuous plaques of dirt. Hairless - areas with hair loss, no skin damage, thinning of the coat, possible hyperkeratosis. Lesion - scab/wound, dermatitis, ear lesions. Swelling - any swollen area. Hairless patch with lesion - hair loss area with scab/wound inside.

Farm:__________________________

Social Behaviour

Date:____________________

Observer:____________________

	Segment										
	Pen										
	Start - End										
	Duration (min)										
Segment scan	Stanting, feed or drinking										
	Lying										
	Total number of animals										
	Lying outside										
	Lying, hindquarter position not visible										
Agonistic	Headbutt										
	Displacement										
	Fighting										
	Chasing										
	Chasing up										
Health	Coughing										
	Comments										

	Segment										
	Pen										
	Start - End										
	Duration (min)										
Segment scan	Stanting, feed or drinking										
	Lying										
	Total number of animals										
	Lying outside										
	Lying, hindquarter position not visible										
Agonistic	Headbutt										
	Displacement										
	Fighting										
	Chasing										
	Chasing up										
Health	Coughing										
	Comments										

Farm:________________________ **Lying Time** Date:______________________

______________________________ Observer:______________________

	Duration (secs)	Collision with Housing Equipment (no - 0, yes - 2, or not observed/heard)	Comments
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
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36			
37			
38			
39			
40			
41			
42			
43			
44			
45			
46			
47			
48			

Farm:________________________ **Avoidance Distance** Date:______________________

________________________ Observer:______________________

10 cm to 200 cm (resolution of 10 cm). If animal touched = 0 cm.

Approx time of feeding: [ ]

	Segment	Group/Pen	Cow ID	Time of Test	Test 1	Test 2 (retest)	Comments
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
32							
33							
34							
35							
36							
37							
38							
39							
40							
41							
42							
43							
44							
45							
46							

Farm: ____________________ Date: ________ Observers: _______________

Pen No.:	
Number of Animals	
Number of water points per pen	
Number of animals using water points	
Water point 1 Type	☐ trough length............cm ☐ tip-over trough length............cm ☐ bowl ☐ bowl with reservoir ☐ trough with balls/anti-frost ☐ nipple drinkers
Cleanliness	☐ no ☐ partly ☐ yes
Are water points functioning?	☐ no ☐ yes
Water flow	☐ <18l/min ☐ >18l/min ☐ trough/tip-over trough
Water point 2 Type	☐ trough length............cm ☐ tip-over trough length............cm ☐ bowl ☐ bowl with reservoir ☐ trough with balls/anti-frost ☐ nipple drinkers
Cleanliness	☐ no ☐ partly ☐ yes
Are water points functioning?	☐ no ☐ yes
Water flow	☐ <18l/min ☐ >18l/min ☐ trough/tip-over trough
Water point 3 Type	☐ trough length............cm ☐ tip-over trough length............cm ☐ bowl ☐ bowl with reservoir ☐ trough with balls/anti-frost ☐ nipple drinkers
Cleanliness	☐ no ☐ partly ☐ yes
Are water points functioning?	☐ no ☐ yes
Water flow	☐ <18l/min ☐ >18l/min ☐ trough/tip-over trough

MANAGEMENT QUESTIONAIRE

Farmer/manager name:______________Farm name:________________Date:__/__/____
Contacts: Farm ID_____________
GPS___________________________
Address____
Telephone________________________
Time of milking ______ / ______ / ______; Milking duration ______
Time of feeding ______ / ______

Herd size

Breed(s): _______________________________ Dairy: ☐ Dual purpose: ☐
Current number of lactating cows on the farm: ______
How many groups are these animals split in to? (by yield, etc.)

- Group 1: ______________________________ No. of cows: __________
- Group 2: ______________________________ No. of cows: __________
- Group 3: ______________________________ No. of cows: __________
- Group 4: ______________________________ No. of cows: __________
- Group 5: ______________________________ No. of cows: __________
- Group 6: ______________________________ No. of cows: __________

Total number of dry cows on the farm: ______
How many are running with the lactating herd? ______
With which group(s)? _______________________________

Total number of replacement heifers on the farm: ______
How many in-calf heifers are running with the lactating herd? ______
With which group(s)? _______________________________

What is the total number of calves on the farm?: ______

Housing – Lactating animals

Cows in cubicles ☐ or straw housing ☐

Outdoor Access

Do cows have access to outdoor loafing area? Yes: ☐ No: ☐
Which groups? _____________________
Between the months of ____________ and ____________
Number of hours per day ____________________
Do cows have access to pasture? Yes: ☐ No: ☐
Which groups? _____________________
Between the months of ____________ and ____________
Number of hours per day ____________________
Presence of tethering: Yes (tie stall) ☐ No (loose housing) ☐

Health

How many cows have died on the last 12 months (died on-farm; were euthanized due to disease or accident; have suffered emergency slaughter)? _________ deaths / _________ average number of animals (with more than 200kg) on farm on the last 12 months

How many cows / heifers have had a difficult calving during the last 12 months?
_________ cows / _________ average number of births on the last 12 months

How many downer cows during the last 12 months? _________ downer cows / _________ average number of animals (with more than 200kg) on farm on the last 12 months

How many milking cows were culled in the last 12 months? ______ cows / _____ average number of animals (with more than 200kg) on farm on the last 12 months

- Due to fertility problems ________________________ cows
- Due to lameness________________________ cows
- Due to mastitis________________________ cows
- Due to accident________________________ cows

Lameness

Do you routinely footbath the milking herd? Yes: ☐ No: ☐
How often? ________ times/week
Is the milking herd routinely foot trimmed?
Yes: ☐ No: ☐ How often? ________ times/year

Mastitis

Individual SCC from the last 3 months – Yes☐ No☐

Management procedures

Disbudding – age _______ weeks / adult cows ☐
Percentage of dehorned animals ________ %
Are they disbudded on farm? Yes: ☐ No: ☐
Thermo-cautery☐ Caustic paste☐ Other _________________________
Use of anaesthetics: Yes: ☐ No: ☐ Which one?
Use of analgesics: Yes: ☐ No: ☐ Which one?

Tail docking – age _______ weeks / adult cows ☐
Percentage of tail docked animals ________ %
Are they docked on farm? Yes: ☐ No: ☐
Rubber ring☐ Surgery☐ Other _________________________
Use of anaesthetics: Yes: ☐ No: ☐ Which one?
Use of analgesics: Yes: ☐ No: ☐ Which one?

Annex 3 – Photographs

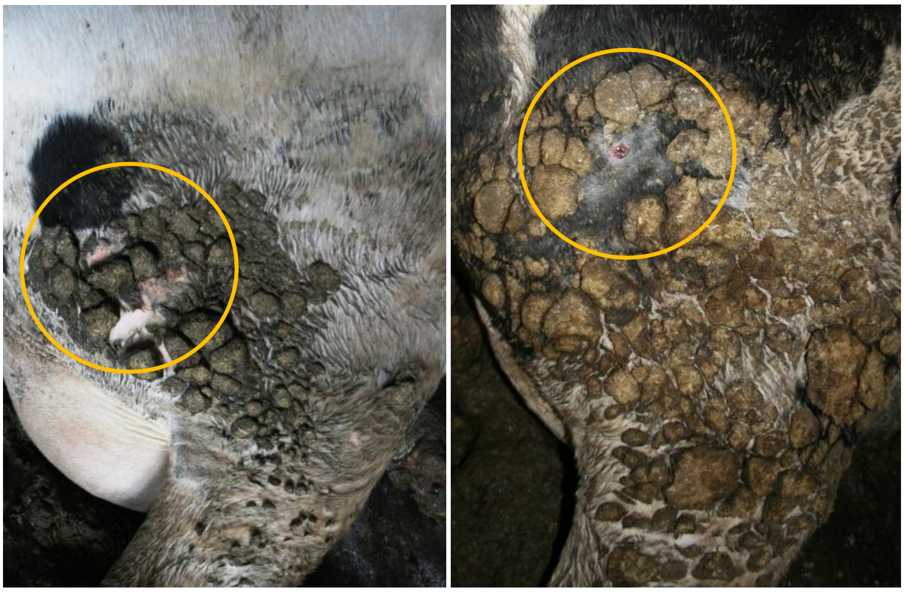

Figure 8 – Two different cows presenting dirt plates with associated hairless patches in the right hindquarter. The yellow circles draw attention to the hairless patches (original photographs).

Figure 9 – Cow lying on a cubicle with its back pressing against the sidebar. The yellow circle draws attention to the presence of multiple swellings (original photograph).

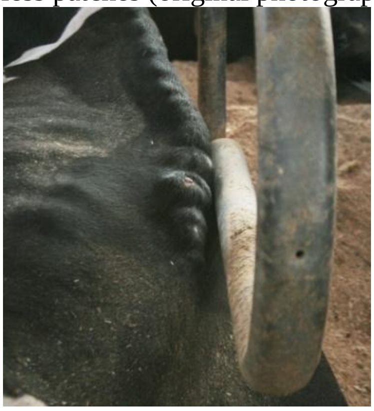

Figure 10 – Zoom of Figure 9 showing the presence of multiple swellings and lesions in the back region, possibly associated with collision against the cubicle while lying down (original photograph).

Figure 11 – Left lower back leg of three different cows with hairless patches of different degrees of severity – from left do right: extensive thinning of the coat; extensive thinning of the coat with some hair loss; area with hair loss and one lesion (original photographs).

Figure 12 – Hairless patches in the tail head accompanied by lesions of dermatitis, similar to those caused by *Chorioptes bovis* (original photographs).

Figure 13 – Integument alterations in the dorsal part of the neck (right photograph) might be caused by pressure against low feed-rails while eating (left photograph; original photographs).

Figure 14 – Dirty hindquarter and udder (original photograph).

Annex 4 – The Welfare Quality principles and criteria that have the major influence on the farms' final score

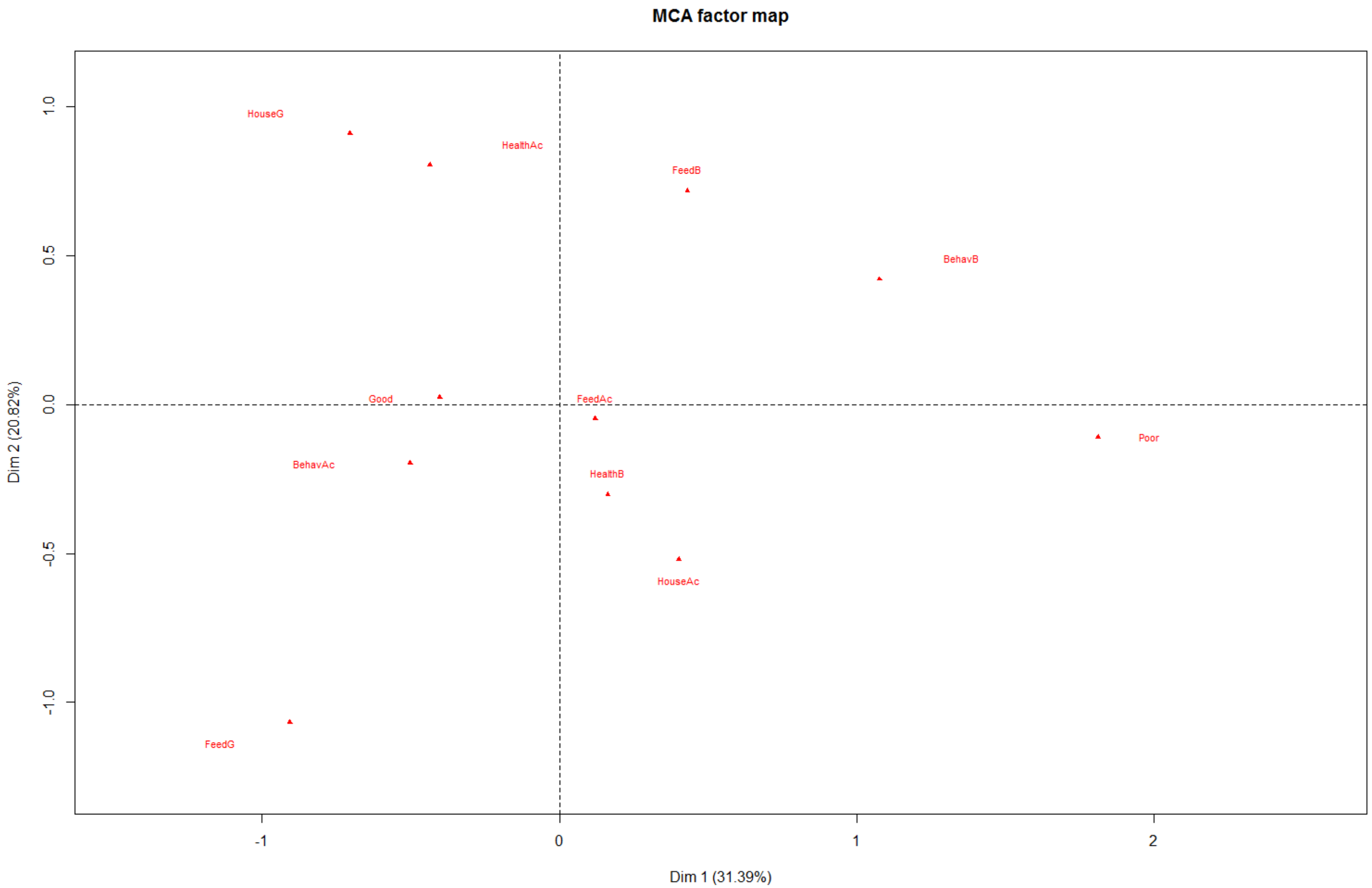

Figure 15 – Results of the multiple correspondence analysis from the welfare principle scores and final farm classification.
Key to acronyms: Feed, good feeding, House, good housing, Health, good health, Behav, appropriate behaviour, Good, farms with 'good' welfare, Poor, farms with 'poor' welfare. In the end of each principle, there is its correspondent score: G, good (50-100), Ac, acceptable (20 to 49) or a B, bad (0 to 19)*.

*For the MCA, scores Excellent, Enhanced, Acceptable and Not classified were substituted by three scores only, to simplify the graphic: Excellent and Enhanced were combined in one – good (G); Acceptable remains equal (Ac); and Not classified is renamed as bad (B).

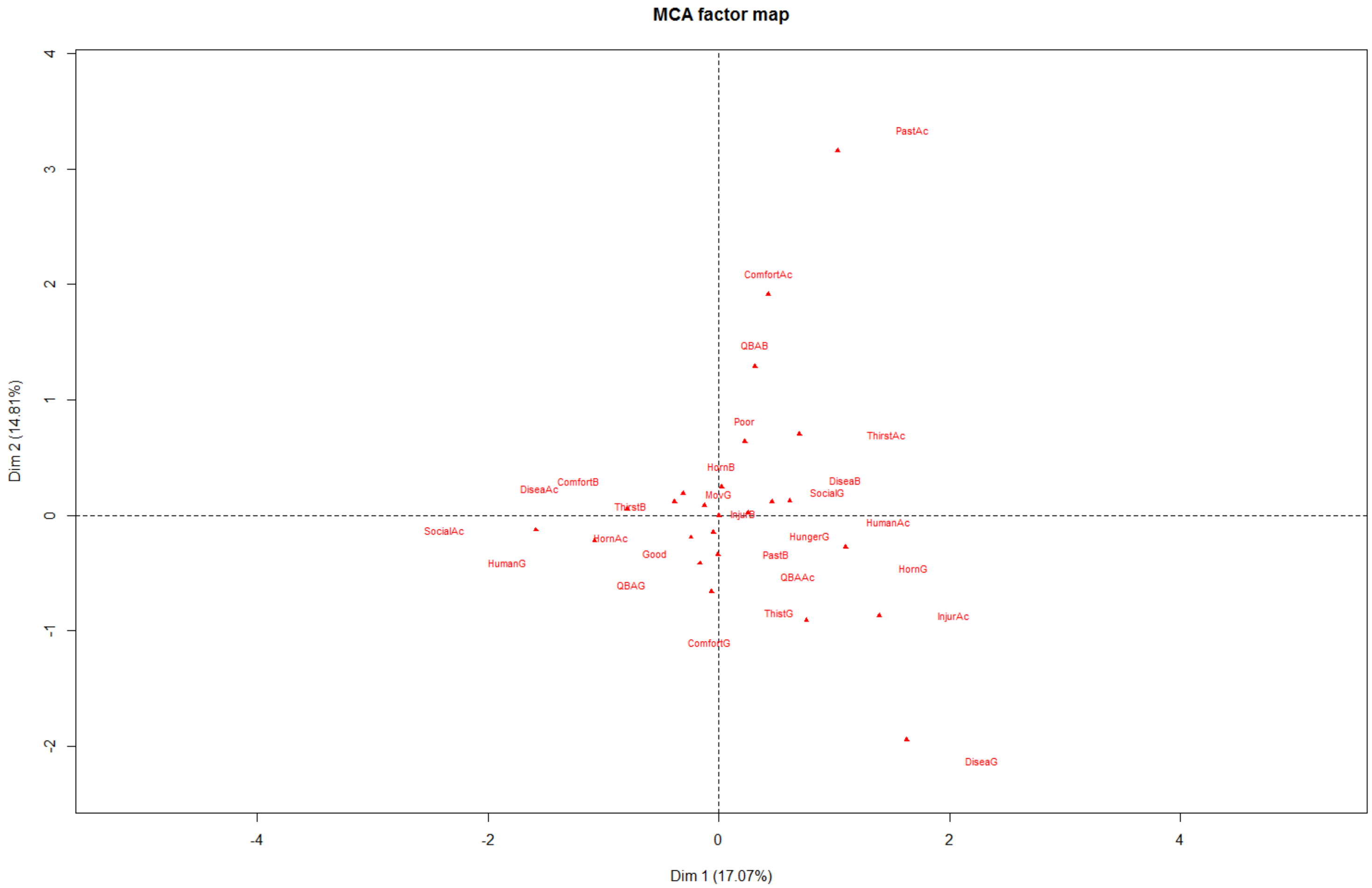

Figure 16 – Results of the multiple correspondence analysis from the welfare criteria scores and final farm classification.
Key to acronyms:, Thirst, absence of prolonged thirst, Comfort, comfort around resting, Mov, ease of movement, Injur, absence of injuries, Disea, absence of disease, Horn, absence of pain induced by management procedures, Hunger, absence of prolonged hunger, Social, expression of social behaviours, Human, good human-animal relationship, QBA, qualitative behaviour assessment, Good, farms with 'good' welfare, Poor, farms with 'poor' welfare. In the end of each criterion, there is its correspondent score: G, good (50-100), Ac, acceptable (20 to 49) or a B, bad (0 to 19)*.

*For the MCA, scores Excellent, Enhanced, Acceptable and Not classified were substituted by three scores only, to simplify the graphic: Excellent and Enhanced were combined in one – good (G); Acceptable remains equal (Ac); and Not classified is renamed as bad (B).

Annex 5 – Building the a model to detect farms with poor welfare (in Waikato Environment for Knowledge Analysis [WEKA])

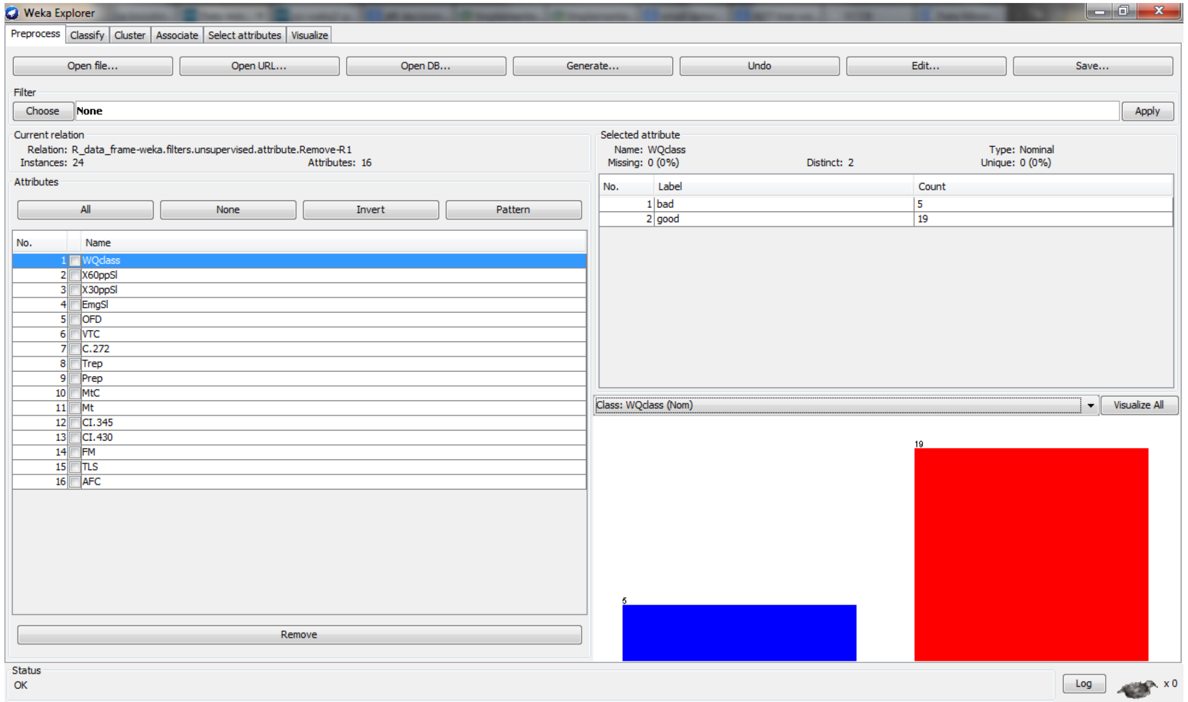

Figure 17 – Before applying Synthetic Minority Over-sampling Technique (SMOTE) to the dataset.
Key to acronyms: AFC, Age at first calving, bad, farms with poor welfare, C.272, Proportion of carcasses with less than 272 kg, CI.345, Proportion of calving intervals lower than the biological (345 days), CI.430, Proportion of calving intervals higher than 430 days, EmgSl, Proportion of emergency slaughter, FM, female/male births ratio, good, farms with good welfare, Mt, Mortality rate (obtained by national database), MtC, Calf mortality (until six months), OFD, Proportion of on-farm deaths, Prep, Proportion of partial carcass rejection, TLS, Total life span, Trep, Proportion of total carcass rejection, VTC, Proportion of carcasses with fat class 'very thin' (class 1), WQclass, welfare quality final classification, X30ppSl, Proportion of cows slaughtered at 30 days post partum, X60ppSl, Proportion of cows slaughtered at 60 days post partum.

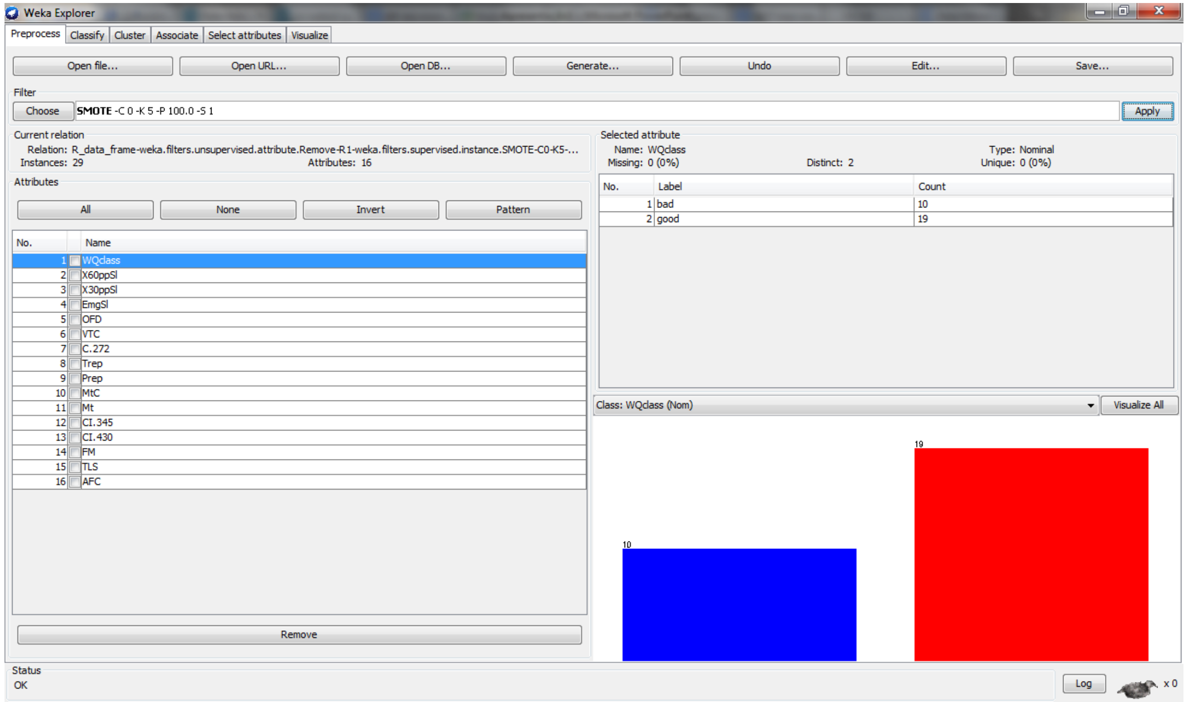

Figure 18 – After applying Synthetic Minority Over-sampling Technique (SMOTE) to the dataset.
Key to acronyms: AFC, Age at first calving, bad, farms with poor welfare, C.272, Proportion of carcasses with less than 272 kg, CI.345, Proportion of calving intervals lower than the biological (345 days), CI.430, Proportion of calving intervals higher than 430 days, EmgSl, Proportion of emergency slaughter, FM, female/male births ratio, good, farms with good welfare, Mt, Mortality rate (obtained by national database), MtC, Calf mortality (until six months), OFD, Proportion of on-farm deaths, Prep, Proportion of partial carcass rejection, TLS, Total life span, Trep, Proportion of total carcass rejection, VTC, Proportion of carcasses with fat class ‘very thin’ (class 1), WQclass, welfare quality final classification, X30ppSl, Proportion of cows slaughtered at 30 days post partum, X60ppSl, Proportion of cows slaughtered at 60 days post partum.

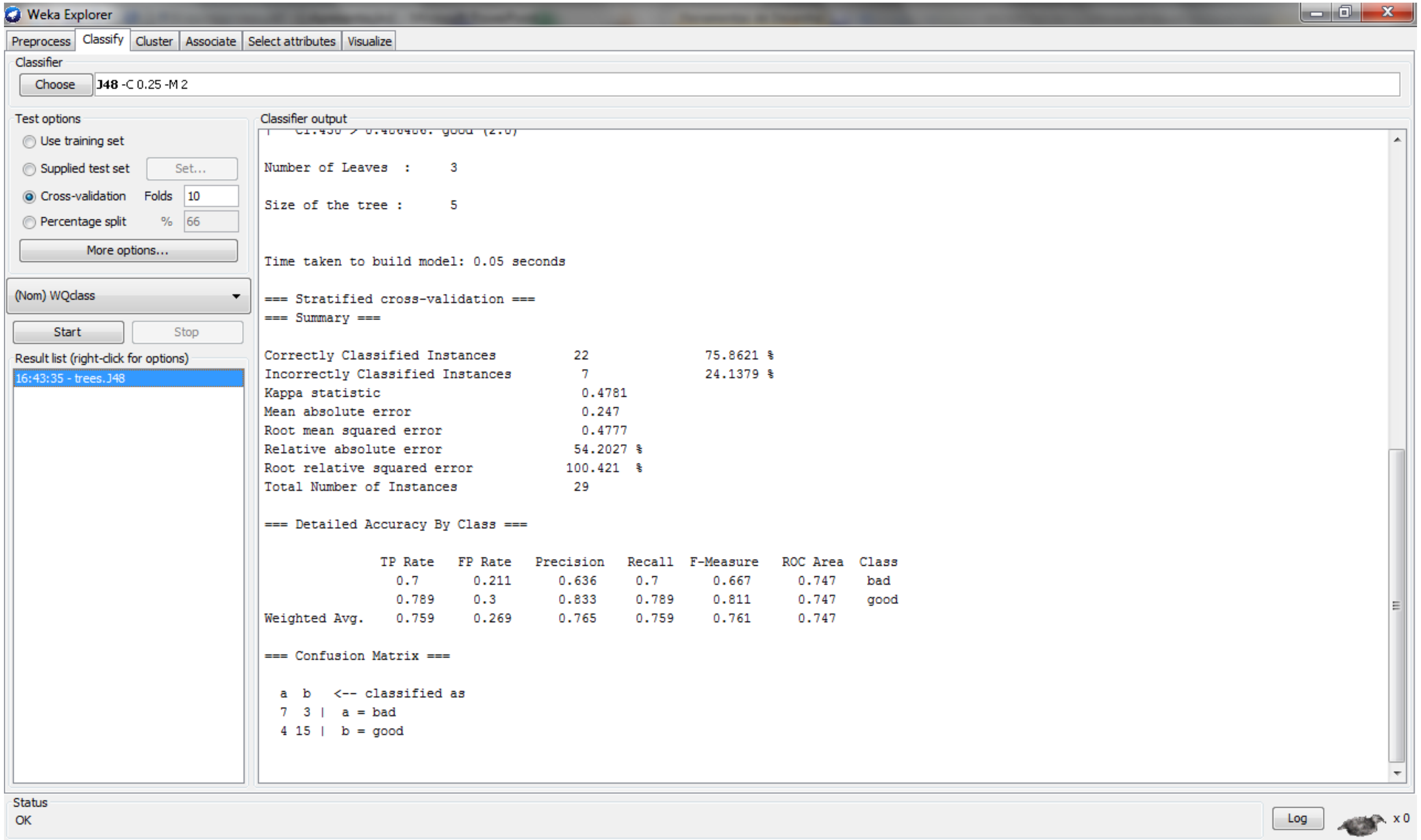

Figure 19 – Results on the model to detect farms with poor welfare created with J48 classifier from Waikato Environment for Knowledge Analysis (WEKA). Key to acronyms: bad, farms with ‘poor’ welfare, good, farms with ‘good’ welfare.