Assessing cattle welfare at slaughter – why is it important and what challenges are faced?

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Abstract

The welfare of animals in the meat industry, especially at the time of slaughter, has become an area of increasing public scrutiny and has prompted research on its assessment, and enhancement. Fundamental factors such as the effects of transport, reactions of the animals to novel environments and underlying commercial pressures which impose 'speed' and 'robustness of action' in the way animals are handled, can pose a challenge when establishing a valid, reliable and feasible welfare assessment protocol for use at slaughter. The purpose of this review is to assess published work on animal welfare at slaughter, with a focus on the current methods used to assess cattle welfare in the slaughterhouse, which are outlined in the scientific and trade literature, and how these relate to the interaction between the environment, the animal, and slaughterhouse personnel.

Keywords: Cattle Welfare assessment; Pre-slaughter stress; meat quality; assurance schemes; abattoir.

1. Introduction

Animal welfare science is a relatively young and rapidly evolving discipline. As well as raising important, contentious and often emotive issues, in certain industries such as food production, the welfare of animals can have a significant economic impact (Gallo & Huertas, 2016; Huertas et al., 2015). Globally the lives of billions of animals are ended every year at slaughterhouses; In 2015, 25.7 million cattle were slaughter in the EU (Eurostat, 2018) and similarly, 28.8 million cattle in the USA. The American beef industry was worth 105 billion USD in the same year (USDA, 2016).

In order to monitor, audit, and optimise the welfare of these animals at the time of slaughter, a valid, feasible and reliable welfare assessment protocol should be used.

2. What is 'good' animal welfare?

The way in which welfare is defined influences the protocol used to measure it (Mason & Mendl, 1993). There is still no universally accepted definition of animal welfare or what constitutes 'good' or 'bad' welfare. Based on a review of animal welfare concepts at the time, Fraser et al. (1997) categorised welfare definitions in relation to their primary welfare 'concern'; for example, 'Functioning' based concerns focus on the health and normal biological functioning of the animal.

It has been suggested by some observers, that welfare is primarily at risk when there is a degree of physiological change greater than a stipulated level (Barnett & Hemsworth, 1990) or during the presence of disease (Taylor, 1972).

Secondly, some authors have categorised welfare around 'natural-living' based concerns, which are centred on the ability of the animal to live a 'natural' life. Dawkins (1980) reported that despite increased risks of disease, allowing an animal to live freely provides optimum welfare. Rollin (1993) famously described how 'good welfare' allows an animal to live according to its *telos*, allowing the fulfilment of the animals' 'natures'.

The third category of concerns are 'feelings-based', describing welfare in terms of psychological wellbeing. Dawkins (1988) suggested that it is the subjective feelings of animals, especially that of suffering or pain, which define welfare, and Duncan (1996) argued that welfare is solely dependent on what animals feel, and that good welfare also involves the presence of positive feelings and the absence of negative ones (Duncan, 2005).

As the study of animal welfare continues to develop and evolve, there has been an increasing consensus of animal welfare scientists that the definition of animal welfare is multidimensional, and thus should include consideration for all three categories of concerns, i.e. 'biological function', 'natural living' and 'feelings' (Lerner, 2008; Manteca & Jones, 2009). However, defining what constitutes good animal welfare around slaughter raises some complex fundamental issues. For example, considering the three categories of concerns outlined above;

- The slaughter of an animal may be seen by some as the ultimate insult to its normal 'biological function'.
- An abattoir cannot be considered a 'natural-living' environment for any livestock species.
- The 'feelings' of animals may be overridden by fear stimulated by the numerous novel stimuli present in a slaughterhouse. (MacKay et al., 2014)

Due to these innate difficulties, in the literature, welfare at slaughter is often defined in relation to the level of stress faced by the animal. However, in a similar way to the use of the term 'welfare', the concept of stress, and what constitutes stress in animals has no clear single agreed definition (Moberg, 2000).

3. Why is welfare at slaughter important?

It is estimated that, if current trends continue, the worldwide consumption of meat will be 76% higher in 2050 than it was in 2005/2007(Alexandratos & Bruinsma, 2012). Although ensuring acceptable welfare standards for this ever-increasing number of animals has significant ethical and moral aspects, good welfare at slaughter also has a potential to significantly influence economic consequences.

3.1 The public and retailers.

The importance placed on animal welfare varies between countries: due to differences in traditions, demographics of livestock, legislation (Villarroel et al., 2001), religion, education, perception and level of economic development (Koknaroglu & Akunal, 2013) and also between different groups (e.g. consumers, retailers, farmers, governments). However it is the level of interest that the general public hold in animal welfare which can drive improvement (Blokhuis et al., 2008; Veissier et al., 2008).

Within Europe, interest in welfare has been growing over recent years. In 2015 a survey to investigate the attitudes towards animal welfare was completed by 27,672 EU

citizens across 28-member states. 94% of respondents were of the view that it is important to protect the welfare of farmed animals, 82% believed that the protection of animals and their welfare should be improved, and 59% indicated that they would be prepared to pay more for welfare friendly products (Special Eurobarometer, 2016). This clear demand for higher animal welfare standards by consumers has been recognised by retailers (Velarde & Dalmau, 2012) and an increasing number of retailers are including welfare requirements into their buying specifications (Mench, 2008).

In 1999, major restaurant and meat buying co-operatives began Hazard Analysis Critical Control Point (HACCP) based welfare audits in commercial slaughterhouses throughout the USA. In order to remain on the approved supplier lists for these companies, which included McDonald's and Wendy's International, individual slaughterhouses had to adhere to specific welfare standards, which were (and are) often more rigorous than those outlined in the legislation (Grandin, 2010). It is in the slaughter plants interest to comply with such standards, as significant economic consequences can result from a failed audit, and, in the most severe case, this can result in subsequent removal from the approved supplier list. This pressure to adhere to good welfare protocols has led to an improvement in welfare practices in the audited plants (Grandin, 2000; Grandin, 2005). It was reported by the same author (Grandin, 2010) that the presence of auditors affects the behaviour of abattoir personnel who "act good" during the audit period, but revert back to poor welfare practices when they are no longer being observed. To combat this issue, some of the large American beef and pork producers have installed CCTV cameras, allowing for remote third-party observation of practice, and visual remote auditing at any time (Grandin, 2010)

3.2 Meat Quality

There is considerable knowledge and published information about the links between pre-slaughter stress, animal handling, and meat quality. Bruising of a carcass appears as a distinct discolouration observable after skinning. A bruise is caused by vascular rupture, leading to blood accumulation in the muscle and other tissues as a result of impact from an animal's environment, a conspecific or due to human-animal interactions (Costa et al., 2006). Bruising can occur at any point prior to an animal being slaughtered. Visual inspection, taking into account the severity, appearance, colour and site of the bruise can help to estimate the age and potential cause of the damage (Strappini et al., 2009).

As well as being indicative of poor welfare practices pre-slaughter, bruising can have an economic impact. Bruised tissue, due to its discolouration and increased capacity for microorganism growth, is unsuitable for human consumption (Strappini et al., 2009) and therefore must be trimmed from the carcass. This process can be time consuming, and may lead to increased labour costs, slower line speeds, reduced efficiency, and a fall in production (McNally & Warriss, 1996). The weight of the tissue removed reduces the yield from that carcass and results in a reduced financial return for the producer. In Uruguay, the estimated annual financial loss due to bruising of cattle carcasses was estimated at eight billion USD (Huertas et al., 2015). Significant rates of bruising in cattle have been reported in studies world-wide (See table 1)

Country	Percentage of carcasses with measurable bruising	Reference
UK	97% 62% 59%	(Jarvis, Selkirk, & Cockram, 1995) (Weeks, McNally, & Warriss, 2002) (McNally & Warriss, 1996)
USA	46.7% 59% 64% (cull cows) 43% (cull bulls)	(McKenna et al., 2001) (Eastwood et al., 2017) (Harris et al., 2017) (Harris et al., 2017)
Mexico	92%	(Miranda-de la Lama et al., 2012)
Italy	66.9%	(Costa et al., 2006)
Uruguay	60%	(Huertas et al., 2015)
Colombia	37.5%	(Romero, Gutierrez, & Sanchez, 2012)

Table 1 Percentage of bruised carcasses, by study location.

A number of factors have been reported to affect bruising prevalence including; transport conditions, the presence of horned animals (Huertas et al., 2010), movement through markets, animal sex, and age (Romero et al., 2012; Weeks et al., 2002). However Strappini et al. (2013) concluded that it was the human-animal interactions at the slaughterhouse, especially during unloading and at stunning which causes the greatest potential for traumatic events. The rough handling of animals, and the use of driving instruments (prods, goads, sticks, whips) pre-slaughter, is positively correlated with levels of bruising (Huertas et al., 2010; Jarvis et al., 1995) and is an important factor to consider in relation to animal welfare. A number of authors have commented that training of personnel in the handling of cattle has the potential to improve welfare and therefore reduce bruising, and also to increase financial returns in commercial slaughterhouses (Jarvis et al., 1995; McNally & Warriss, 1996; Strappini et al., 2013).

It is important to note that the use of electric prods or goads does not usually result directly in bruised tissue (Strappini et al., 2013; Weeks et al., 2002), however the stress caused by their use in cattle can contribute to meat quality defects (Costa, 2009; Ferguson & Warner, 2008). Warner et al. (2007) demonstrated that acute stress, induced by electric goad use in cattle 15 minutes prior to slaughter (6-8 prods), detrimentally affected the water holding capacity of the loin muscle and the consumer acceptability of 21-day aged loin meat. Consequently, in the UK, retailers have applied pressure on slaughterhouses to significantly restrict the use of electric goads on livestock during lairage.

Dark Cutting Beef (DCB) occurs when cattle are exposed to physical or psychological stress for a period of time prior to slaughter. Prolonged or chronic stress results in a severe depletion of muscle glycogen leading to a reduction in lactic acid production post mortem. The muscle has a higher than optimum pH level as it cools, and the meat appears dark and dry resulting in reduced customer acceptability (Tarrant, 1989). The lack of sufficient acidification of the meat has an important consequence in that it increases the capacity for bacterial growth, and therefore the rate of meat spoilage (Chulayo & Muchenje, 2015).

Reductions in customer satisfaction and increased rates of spoilage can have significant economic impact; at the time of the 1995 national beef quality audit in the USA, 6 USD per carcass on average was being lost due to 'dark cutting beef' (DCB) (Smith et al., 1995), and with 35.6 million cattle being slaughtered in the same year (USDA, 1996) the estimated total annual loss amounted to over 210 million USD. This figure had reduced to $5.43 per carcass in 2000 however this still totalled a 164 million USD loss to the American beef industry (Miller, 2007). Similarly, the Australian beef industry report the potential annual loss due to DCB to be in the region of $36 million AUD (MAL, 2014). While in Canada the annual loss is estimate at $1.4million CAD (Holdstock et al., 2014)

In a similar circumstance to bruising, a number of factors have been reported to affect the prevalence of DCB. These include; transport conditions and duration, the sex of the animal, the level and intensity of physical activity, lairage duration and conditions, interaction with conspecifics, method of marketing, and animal handling practices (Ferguson & Warner, 2008). The importance of education and training in minimising the stress caused by pre-slaughter procedures has been highlighted by a number of authors (Costa, 2009; Ferguson & Warner, 2008).

4. How can welfare be measured in an abattoir environment?

Establishing a valid, reliable, repeatable welfare assessment protocol could allow the effects of welfare improvement measures to be quantified. Measuring welfare in a commercial slaughter environment can prove challenging, because some of the most sensitive physiological criteria for quantifying welfare such as heart and respiratory rate (Miranda-de la Lama, 2013) are not readily feasible to be assessed in the complex environment of the slaughter area. Commercial pressures, high processing speeds and the layout of facilities may lead to difficulties in visually observing, and physically measuring animal-based parameters.

However, welfare at slaughter assessment methods do exist – some of these protocols were initially developed to assess the welfare of livestock species on farm, and have been adapted for use in the slaughterhouse. While others have been developed specifically for use in the abattoir.

4.1 Animal based scoring systems

One of the most widely recognised welfare 'concepts' is The Five Freedoms. Developed by the Farm Animal Welfare council in 1965 (Brambell, 1965). This 'concept' has had a significant impact on animal welfare and the five freedoms have formed the basis for EU legislation, recommendations and welfare education (McCulloch, 2013).

The Five Freedoms are: (FAWC, 2009)

 – Freedom from hunger and thirst – by ready access to water and a diet to maintain health and vigour.

- Freedom from discomfort – by providing an appropriate environment including shelter and a comfortable resting area
- Freedom from pain, injury and disease – by prevention or rapid diagnosis and treatment.
- Freedom to express normal behaviour – by providing sufficient space, proper facilities and appropriate company of the animal's own kind,
- Freedom from fear and distress – by ensuring conditions and treatment, which avoid mental suffering.

In a critique of the Five Freedoms, McCulloch (2013) concluded that although sufficient to analyse welfare, their focus on ideal states means the framework is not sufficient to determine acceptable levels of welfare. Other authors have commented on the generality of the criteria and the overlap between the freedoms, for example - injury can affect the ability of an animal to express normal behaviour (Botreau et al., 2007). It is the lack of 'standards' (absolute values) set out by the five freedoms which means that the framework cannot be directly and successfully applied to measure welfare, or the effects of welfare improvement measures in a commercial slaughterhouse setting.

The Five Freedoms however, provide a basis for the four main principles behind the Welfare Quality Project (Blokhuis et al., 2008).

- Good feeding
- Good housing
- Good health
- Appropriate behaviour

The Welfare Quality project was developed to integrate animal welfare measures into the food chain (Velarde & Dalmau, 2012). Protocols have been designed to assess welfare in different livestock species in a range of environments and are based on four main principles above.

Within these principles, twelve criteria have been formulated, and animal-based measures for these criteria were developed for use with different species, both on-farm and at the abattoir. (See Table 2). When using the Welfare Quality protocol to assess cattle welfare both on farms and in the slaughterhouses of Latin America, Huertas et al. (2009) suggested the inclusion of further indicators of the human-animal relationship, and measures to assess cattle handling. These included; use of driving aids, assessment of aggression towards the animal, human and animal vocalisation, speed of driving and the incidence of 'hits' (impacts) with gates. The recommendations of Huertas *et al* are addressed by Sandström (2009) in a refined Welfare Quality protocol developed after trials in five Swedish cattle slaughter plants. Alongside measures of human-animal interaction and cattle behaviours, the modified assessment includes gathering general plant information and data regarding the environmental conditions of the lairage. Sandström outlines the need to prioritise the observation of unloading and driving into the lairage. However, it was reported by Dalmau et al. (2009), that measuring welfare at unloading is dependent on lorries arriving when an assessor is available, and at plants with a small daily throughput, there can be long delays between arrivals, or fewer lorries arriving per day than the stipulated sample size for particular measurements.

It has also been noted by Brandt and Aaslyng (2015) that the Welfare Quality protocol has no measure of the expression of social or other behaviours at slaughter, and therefore potential indicators of welfare compromise may be missed, for example mixing of unfamiliar conspecifics or fighting. Despite this, the modified Welfare Quality assessment developed by Sandström is a thorough and broad welfare assessment protocol incorporating a detailed range of animal and environmental based measures. For this to be achievable, two inspectors are required for each assessment. Sandström emphasises the need for rigorous inspector training, stating the requirements for inspectors to have 'sound knowledge of animal physiology and behaviour, adequate practical experience, and knowledge about human and animal safety aspects'.

The use of the Welfare Quality structure, may be beneficial in providing a detailed welfare report for slaughter facilities and also in the assessment of the effects of welfare improvement measures. However, due to its complexity, both time and labour requirements and the need for highly trained inspectors leaves questions over its practicality for use in more regular welfare monitoring within plants.

Principle	Welfare Criteria	Measures
Good feeding	Absence of prolonged hunger	Food supply
	Absence of prolonged thirst	Water supply
Good housing	Comfort around resting	Flooring, bedding
	Thermal comfort	*Criterion is not applied in this situation*
	Ease of movement	Slipping, falling, freezing, trying to turn, turning around, moving backwards
Good health	Absence of injuries	Lameness, bruises
	Absence of disease	*Criterion is not applied in this situation*
	Absence of pain induced by management procedures	Stunning effectiveness
Appropriate behaviour	Expression of social behaviour	*Criterion is not applied in this situation*
	Expression of other behaviours	*Criterion is not applied in this situation*
	Good human-animal relationship	Vocalization, coercion
	Positive emotional state	Struggling, kicking, jumping in stun box, trying to turn, turning around, moving backwards.

Table 2 Welfare Quality protocol to assess cattle welfare at the slaughterhouse (Velarde & Dalmau, 2012)

There is a considerable level of overlap between the principles of Welfare Quality and the Five Domains welfare model; (Mellor, 2017)

- – Nutrition
- – Environment
- – Health
- – Behaviour

These domains above allow for the systematic evaluation of an animals internal state and external circumstances. Within this model, and unlike that of Welfare Quality, Mellor has developed a fifth domain "Mental State". This domain contains measures of both positive and negative mental affect, for example the negative affect of thirst and the positive affect of the quenching pleasures of drinking or the negative affect of boredom and the positive affect associated with being engaged. There is a movement in modern animal welfare science, and to a degree in policy driven initiatives, towards the promotion of positive animal welfare states and the minimising of negative states. The Farm Animal Welfare Committee (FAWC, 2009) of Defra has proposed the use of the 'good life' concept (FAWC to promote the idea of '*minimum standards of animal welfare being assessed against an animal's quality of life, that an animal should have a 'life worth living' from its point of view and that an increasing number should have a 'good life'.* The concept of a life worth living is quite challenging and has yet to be widely incorporated into policy and welfare assessment, but does promote discussion on how models such as the five domains or Welfare Quality actually address complex issues of animal experience. The use of the Five Domains model may help to incorporate this change in emphasis. (Mellor & Beausoleil, 2015) However, at the time of review there is no current use of this model in a slaughter setting. The measures contained in the Welfare Quality protocol (See Table 2.) are predominantly focused on the reduction of welfare comprise. Further work is warranted on the promotion of positive welfare states within abattoirs and any impacts this may have on animal welfare and meat quality.

The welfare scoring systems developed by Grandin (2010) have been used in a commercial slaughter setting for over ten years (Dalmau et al., 2016). Developed specifically for use in the slaughter industry, the focus of the protocol is on objective animal based standards that can be numerically scored and easily measured, under commercial conditions (Grandin, 1998b). The five animal based measures used are; (Grandin, 2010).

- – Percentage of animals stunned effectively on the first attempt
- – Percentage of animals that remains insensible after they are hung on the rail
- – Percentage of animals that fall during handling
- – Percentage of animals that vocalize during handling and stunning
- – Percentage of animals moved with an electric goad.

The system is based on the HACCP protocols commonly used to monitor food hygiene and safety, where a small number of measures can be used to identify a larger number

of potential risks (Grandin, 2006). For example, an ineffective stun could be the result of poor equipment, inadequate restraint or lack of training.

These 5 measures are used to audit welfare at slaughter, by both the US Department of Agriculture (USDA), and major restaurant co-operations. As mentioned previously there is a significant economic incentive to pass retailer audits, which has led to significant improvement in welfare practice.

Grandin (2006) used vocalisation as one of the five measures of welfare. There is evidence that vocalisation scoring can be used to identify areas of severe welfare compromise in the slaughter plant; Grandin (2001) reported that reducing the pressure on a bovine's neck reduced the percentage of cattle vocalising from 23% to 0%, while Bourguet et al. (2011) found that excessive pressure from the restraint device caused 25% of cattle to vocalise. In a separate study by Grandin (1998a) it was reported that in 110 of 112 cattle assessed, vocalisations occurred directly after an adverse event such as use of an electric prod, slipping, or excessive pressure being exerted by restraining equipment. It is important to note however, that in plants studied where the electric goad was used on 90% and 76% of the cattle, only 32% and 12% cattle vocalised respectively. It is clear that a large percentage of cattle that experience adverse welfare – such as being given an electric shock by a goad or receiving excessive pressure during restraint - may not vocalise, and therefore will not be scored using the Grandin criteria. A further difficulty arises when those staff handling live animals, having been advised by their managers to reduce goad use in order to pass an upcoming audit, hit or poke animals in sensitive areas when they balk or refuse to move (Grandin, 2001).

It is important to note that the Grandin scoring system states that vocalisation occurring in the lairage pens should not be tabulated, therefore, potentially, this misses the reporting of welfare risks during lairage, a significant part of the pre-slaughter operation.

On a practical level, Grandin (1998b) also stipulates that all vocalisations are scored regardless of intensity, which may prove difficult in a noisy slaughterhouse environment. Conversely cattle are capable of vocalising in a variety of states (MacKay et al., 2014) not just one of adverse welfare. As there is no simple system to differentiate a vocalisation in reaction to an adverse event compared to a non-adverse event, there is thus the possibility of a plant scoring highly on the vocalisation criteria even when the cattle are experiencing adequate welfare conditions. Notwithstanding the challenges associated with vocalisation scoring, in an extensive literature review, Losada-Espinosa et al. (2018) stated that valid indicators of welfare at slaughter for cattle are falling during handling, vocalisation and human-animal interactions.

There are two basic purposes of welfare audits and assessments. The first is to locate severe problems, allowing government officials or retailers to identify whether an abattoir requires corrective actions or removal from an approved supplier list. The second is a more in-depth welfare assessment. The strengths of the Grandin welfare scoring system is that it is simple, easy to use and straightforward to teach to auditors and plant personnel. However, the limited criteria, and the limited behavioural measures used, do not allow for a full assessment of welfare risks. There is no reference to the health, injuries or husbandry of the animals, prevalence of lameness.

Measurement of welfare risks associated with comfort such as thermal discomfort or overcrowding are also lacking. In a similar way to the Welfare Quality protocol, Grandin's system would also benefit from the inclusion of validated measures of human-animal interaction.

Bourguet et al. (2011) used a more detailed set of welfare assessment measurements to assess the behavioural and physiological reactions of cattle in a commercial French abattoir. Alongside slips, goad use and vocalisations (as included in Grandin's protocol), Bourguet and others included backwards movement, urination, kicks, compression (both by other animals and by facilities), bumping into the rear door, and head lifting. The protocol also included the timing of various procedures and delays; such as delays in stunning and the time spent in the slaughter corridor. Biological parameters such as plasma cortisol and haematocrit were analysed at exsanguination, plus meat pH and carcass temperature were measured one-hour post mortem.

The relatively large amount of quantitative data collected by these methods allowed for a more detailed picture of a slaughter plant's pre-slaughter procedures, and their effects on animal welfare and meat quality. However, this study was carried out in an abattoir which slaughtered 240 cattle a week, in comparison to those plants implementing Grandin's protocol - some of which process over 300 cattle an hour (12,000 animals a week). The high chain speed (processing speed) in large plants would pose a challenge when attempting to collect a large number of measurements, especially where numerous measures may best be assessed simultaneously, but at different sites along the processing line.

4.2 Qualitative Behaviour Assessment

Stockman et al. (2012) trialled a quick, non-invasive, qualitative based welfare assessment procedure in slaughterhouses in Australia. Fifteen observers, comprising university staff, students and members of the public observed videos of 28 cattle as they passed through a corridor prior to the stun box. Free choice profiling was carried out, where the observers chose their own descriptive terms to describe the cattle. The observer scores for each descriptive term were then recorded on a visual analogue scale (a continuous recording scale) after watching the videos for a second time. It was found that cattle with a high plasma lactate level at slaughter (indicative of a corticosteroid-mediated stress response) were more likely to be scored as more nervous by the observers. Stockmen et al also reported a high level of observer agreement and suggested that qualitative behavioural analysis (QBA) could be a rapid, effective way to assess behaviour and welfare pre-slaughter. This however was a very small study – with only 28 cattle observed and with the methods relying heavily on access to appropriate video footage of the livestock. It is likely that QBA could be more effectively applied in plants with slower line speeds. In large North American facilities which slaughter thousands of animals daily, the continuous movement of a large number of animals may prove challenging when describing and assessing the welfare of individual animals.

A combination of objective behavioural observations and subjective assessment scales were used to assess the human-animal interaction at four Indonesian abattoirs and

reported by Doyle et al. (2016). The data was collected from videos recorded in the raceway and lairage. It was found that a subjective cattle temperament scale did not correlate with any of the objective behaviours measured, however the subjective handling score was well correlated with the majority of behaviours. This supports the finding of Stockman (2012) that QBA can be used to assess behaviour and welfare at slaughter. However, the same potential limitations applied as described above, with the requirement for suitable video footage and the relatively small number of cattle observed in this study (the Indonesian abattoirs processed 25 or less cattle per day). Some further validity measures would be required for use of the subjective scoring used by Doyle et al (2016), and intra-observer reliability was not tested in these studies, and the observers were not blind to the objective handling scores when using the subjective assessment scales.

Inter-Observer Reliability (IOR) was tested by Dalmau et al. (2010) when assessing four welfare measures (Lameness, slipping, falling, fear-*based on four indicators*) at Spanish and Belgian pig abattoirs. Unlike the Australian and Indonesian studies, the observers in the Dalmau study (2010) were watching the pigs *in situ*, and a large number of animals were assessed (1604 for lameness, falling and slipping, 2632 for fear). IOR varied from low to high dependent on the measure being scored, and the assessment location in the abattoir. In areas of low IOR, observers commented on the difficulty in obtaining a clear non-obscured view of the animals. Assessment of four behavioural parameters for fear proved challenging when the assessor was attempting to assess all of these measures simultaneously, and this factor resulted in a reduced IOR. It is clear that increasing the number of measures would provide more information, or information of 'better quality', but that this would take more time to implement. It was also apparent in this study that there was also the potential for the interference of measures (one measure result interfering with another, or one measure being a 'proxy' for another), which should be taken into consideration when analysing data resulting from these kinds of 'in situ' assessments.

4.3 Weighted protocols

In attempts to establish a welfare assessment system that included the most relevant welfare measurements, Hultgren et al. (2014) developed an ethogram in which the list of behavioural parameters, based on the Welfare Quality protocol, were allocated an 'animal welfare score' which was constructed by five animal welfare experts. A score of 1 was a weak sign of impaired welfare while a score of 3 was a strong sign (an indicator of poor welfare). The counts for each behaviour were multiplied by the allocated animal welfare score. The protocol also included a separate ethogram for human-animal interactions, with associated animal welfare scores e.g. hitting with a tool, using an electric goad and tail twisting. Maria et al. (2004) also used a welfare weighted scoring system to assess 'stress' in cattle during loading and unloading. The 'reliability' (actually practical application) of each observation was taken into account in the scoring system with the example given by the author of the challenges associated with measuring vocalisations in a noisy environment.

As some behaviours are likely to be more indicative of poor welfare, a weighted scoring system may be beneficial in producing an overall welfare score which more closely reflects the impact on the animal. However, it can be argued that any welfare assessment protocol reliant on observing behaviour alone, cannot reliably measure all instances of impaired welfare. Mild pain, mild distress and negative mental states may not be reflected in a behaviour change which can be measured by an observer.

4.4 Biochemical & haematological measures

Measuring changes in biological (biochemical, haematological) parameters can be used as an indicator of stress and may be able to detect unobservable responses. Urine catecholamines can be used as an indicator of pre-slaughter stress, however establishing a clear relationship with meat quality requires more work (Muchenje et al., 2009). Hemsworth et al. (2011) reported that cortisol concentration at exsanguination in cattle correlated with negative animal handling pre-slaughter, (for example increased electric goad use), however causality could not be assumed. Conversely Cockram and Corley (1991) reported a negative correlation between plasma cortisol concentration at sticking (exsanguination) and the number of times cattle were hit with a pipe. They described that the behaviour of cattle was the same when hit with the pipe regardless of cortisol concentration.

As an individual animal's response to stress is a complex interaction of previous experience and genetic factors (Grandin, 1997) a single blood parameter measurement at the point of slaughter is not likely to be sufficient to thoroughly assess pre-slaughter welfare. Obtaining a baseline measurement would be difficult in a commercial slaughter plant, as blood would have to be taken from animals in lairage, and the invasiveness of the procedure could influence any results. Certain parameters such as cortisol may fluctuate due to non-aversive events such as the effects of normal circadian rhythms.

There is some evidence of links between stress at slaughter and altered early post-mortem muscle pH; Bourguet et al. (2011) reported that female cattle slaughtered without stunning had a faster muscle pH decline than females slaughtered post stunning. Similarly bulls with an increased heart rate (indicating a stressed state) just prior to slaughter had a more rapid early post-mortem muscle pH decline (Bourguet et al., 2015). The rate of muscle pH decline has the potential to indicate the level of stress experienced by an animal during the slaughter process, however, as with some other forms of biological measures, does not allow for the 'pinpointing' of potential stressors.

In a systematic review of cattle welfare indicators, Losada-Espinosa et al. (2018) reported that although the majority of biological measures are potentially valid for assessing welfare, their feasibility for use in the abattoir was in reality 'low' in all cases. Therefore, although biological measurements may be useful as part of an overall welfare assessment protocol and assessment of meat quality they probably cannot be used exclusively (i.e. as the sole measure) in a commercial setting.

5. Summary conclusions

There is currently significant pressure on Food Business Operators to protect the welfare of the animals that pass through their slaughter premises. Alongside the potential of failing to meet legislative and customer requirement, poor welfare at slaughter can result in poor quality meat and meat products.

In order to assess the welfare at a specific plant and also to allow analysis of the effects of welfare improvement measures (such as the influence on welfare of personnel training), it would be beneficial to utilise a simple, practical and 'encompassing' (i.e. taking in a range of welfare domains) welfare assessment protocols.

The 'ideal' welfare assessment protocol should include measures that would be sensitive enough to detect real welfare change. For example, if the effects of training were to be evaluated, the number of lame animals at unloading may be of limited use, but the number of animals identified as lame and handled appropriately by staff may be an interesting, sensitive, and valid measure. However, as discussed, defining and assessing animal welfare at the abattoir is inherently challenging. Currently no universally accepted measurement protocol has been devised.

Assessment protocols published in the scientific literature outline a range of methods and measures used in assessing welfare at slaughter. Whilst each protocol is associated with potential strengths and weaknesses, it is likely that to produce an optimal welfare assessment system, the particulars of individual slaughter plants will need to be taken into consideration. A small percentage of slaughterhouses have developed self-auditing protocols (Mench, 2008), and this 'self creation' of assessment methods, emphasises that there is an ongoing need for a welfare assessment system that is straightforward, effective and can also be carried out by people already involved day to day in the industry, i.e. plant personnel, rather than being limited to visiting animal welfare scientists.

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