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Tropical paradise: Is it for cows?

Animal welfare of cattle raised under tropical conditions

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Abstract

Consumers in developing countries in the tropics are becoming more aware of farm animal welfare issues. Assessment protocols and changes to old harmful practices have become essential for the survival of small enterprises, which are the sole livelihood for many people living in poverty. This thesis investigated general animal welfare in cattle raised under tropical conditions and sought to identify areas in need of improvement. Welfare Quality® protocols were applied to assess 34 dual-purpose farms in Mexico and 60 farms grouped into three farming systems (intensive, semi-intensive and extensive) in Costa Rica. Clear differences between the farming systems were found and some changes to the Welfare Quality® protocols were suggested to obtain more accurate assessments. In a further comparison of animal welfare in tropical cattle between the rainy and dry seasons, some differences were detected, with the rainy season representing a greater risk to animal welfare. One of the major animal welfare hazards observed was performing painful procedures without any pain relief. Thus, a study was performed in which three different protocols for pain relief were compared with a non-pain-relief control group during hot-iron branding of heifers in Brazil. Assessments of signs of pain showed that the groups did not differ significantly according to most pain indicators, but some variables indicated inadequate animal welfare in the control group. In general, the results obtained in this thesis demonstrate that the animal welfare status of cattle raised under tropical conditions can be very variable. Broadly, the Welfare Quality® principles of good housing and appropriate behaviour can be considered strengths in the region. However, the principles of good feeding and good health were major weaknesses for the majority of farms assessed in this thesis. The good health principle is particularly compromised by the performance of statutory painful procedures on animals without the use of pain relief.

Keywords: Animal welfare, assessment, cattle, tropics, family farming, extensive farming.

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Dedication

To all the cows of the world, especially those who live in the tropics.

We raise them for us; that means we owe them some respect. Nature is cruel but we don't have to be.

Temple Grandin

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List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I. Hernandez, A., Berg, C., Eriksson, S., Edstam, L., Orihuela, A., Leon, H., Galina, C.S. (2017). The Welfare Quality® assessment protocol—How can it be adapted to family farming dual purpose cattle raised under extensive systems in tropical conditions? *Animal Welfare 26*, 177-184.

II. Hernandez, A., Estrada König, S., Romero Zuñiga, J.J., Galina, C.S., Berg, C., DiGiacinto Villalobos, A. (2017). Implementation of the Welfare Quality® protocol in dairy farms raised on extensive, semi-intensive and intensive systems in Costa Rica. *Journal of Animal Behaviour and Biometeorology* 5, 132-138.

III. Hernandez, A., Berg, C., Westin, R., Galina, C.S. (2018). Seasonal differences in animal welfare assessment of family farming dual-purpose cattle raised under tropical conditions. *Animals* 8, 125.

IV. Hernandez, A., Trindade, P.H.E., Paranhos da Costa, M.J.R., Jung, J., Berg, C. Comparison of three pain control treatments while performing facial hot-iron branding in young calves in Brazil and short- and long-term effects on animal welfare (manuscript).

The contribution of Adalinda Hernández to Papers I-IV was as follows:

I. Was involved in methodology planning and data collection. Had main responsibility for the analyses and compilation of results, and for writing and completing the manuscript, with regular input and support from supervisors.

II. Was involved in methodology planning and data collection. Had main responsibility for the analyses and compilation of results, and for writing and completing the manuscript, with regular input and support from the co-authors and supervisors.

III. Was involved in methodology planning and data collection. Had main responsibility for the analyses and compilation of results, and for writing and completing the manuscript, with regular input and support from supervisors.

IV. Was involved in methodology planning, data collection and compilation of results. Had main responsibility for writing and completing the manuscript, with regular input and support from the co-authors and supervisors.

Abbreviations

ANI	Animal Needs Index
AW	Animal welfare
CO	Control group
FAO	Food and Agriculture Organization of the United Nations
FAWC	Farm Animal Welfare Council
IFAD	International Fund for Agricultural Development
INRA	National Institute of Agricultural Research
OIE	World Organization for Animal Health
QBA	Qualitative behaviour assessment
UN	United Nations
WQ®	Welfare Quality®

1. Background

During recent decades, farm animal welfare has increasingly become an important issue for members of modern societies. This is particularly the case in developed economies, where concerns about animal welfare are widely discussed and a broad range of people such as activists, scientists, legislators and farmers are involved and are working together to improve animal welfare. In developing countries, animal welfare concerns have become apparent more recently, as people in those countries are rapidly achieving higher purchasing power and are becoming more aware about their consumption habits and the production conditions of products available on the market.

As changes are rapidly occurring and demands for fair treatment of animals and the environment increase, some farm enterprises are being left behind. This is either because they are unable to compete against larger and more well-established animal production systems or are not capable of providing adequate proof of good animal welfare and sustainable conditions that modern consumers demand. This is primarily affecting small producers in developing countries, such as those situated in tropical areas of the world. There, they are adding to a number of social problems already affecting the region, such as increasing migration of rural populations to cities, increased poverty and inequality, and abandonment of traditional, possibly more sustainable, forms of animal production.

2. Introduction

2.1 Animal welfare

Animal welfare is a commonly used term, but its meaning and definition can vary greatly, depending on the criteria used in judging what a good life for animals means and how they deserve to be treated (Fraser *et al*., 1997). A simple definition of 'animal welfare' is that the animal is healthy and has what it needs (Dawkins, 2008). However, this definition may not entirely cover what 'animal welfare' comprises. Among the numerous definitions of animal welfare, three main types have emerged.

The most commonly accepted definition in the past mainly focused on the biological function and the physical environment in which the animals were kept: "if an animal is healthy and producing well, it is faring well" (Blood & Studdert, 1988). In 1986, Broom described "welfare" as the state with regard to an individual's attempts to cope with its environment. This definition led to research focusing on physiological measures, such as heart rate and plasma cortisol, to evaluate animal welfare (Broom, 1991). However, this approach has the obvious limitation of not considering what the animals are actually experiencing while coping with their environment (Mellor, 2016).

In a later definition, it was proposed that what an animal feels entirely constitutes its welfare, since feelings have evolved to protect the primary needs of animals, so that "if an animal feels well, it is faring well" (Duncan, 1996). Under this definition, animal welfare is limited to behaviour and signs of emotions such as pain, fear or frustration, and focuses on decreasing or eliminating negative emotions and increasing positive emotions. The subjective nature of emotions and the limitations related to knowing for

certain what other individuals are feeling have been the main criticisms of this theory.

The third definition is based on the belief that animal welfare is best when animals can live according to their nature (Rollin, 1981; Kiley-Worthington, 1989) and when the ethological needs of the animals are fulfilled and they are able to perform their full range of behaviours (Kiley-Worthington, 1989). Negative experiences such as physical and mental suffering, cold or fear of being preyed upon could be acceptable under this definition (Hewson, 2003). This approach is rather widely accepted by the public, but it is not entirely accepted by scientists, who consider that it cannot be the sole basis for ensuring proper welfare (Hewson, 2003).

Animal welfare scientists propose considering all three definitions and suggest that animal welfare involves the ability of an animal to function biologically, its mental state and emotions, and its "natural life", as these are all interrelated and ethically important (Fraser *et al*., 1997; Appleby, 1999; Keeling *et al*., 2011). It has also been suggested that having positive interactions with humans should be included, if it can be proven that this improves animal health or provides something that the animal wants (Hemsworth et al., 2009).

The holistic approach above was applied in this thesis. It is summarised in the definition proposed by the World Organization for Animal Health (OIE) Terrestrial Animal Health Code, which states that animal welfare is "*the physical and mental state of an animal in relation to the conditions in which it lives and dies*". This document also states that "*an animal experiences good welfare if the animal is healthy, comfortable, well nourished, safe, is not suffering from unpleasant states such as pain, fear and distress, and is able to express behaviours that are important for its physical and mental state*" (OIE, 2019).

2.2 Animal welfare assessment

To address societal concerns about animal welfare, it is clearly necessary to determine actual animal welfare. Standardised protocols have thus become essential tools for assessing the true animal welfare status of production animals and how it can be enhanced. However, achieving consensus on

assessing animal welfare is not a simple task, as different people prioritise different aspects (Fraser *et al*., 1997). For some, physical health and freedom from pain and injury might be the most important aspects, while some may consider the emotional state of the animal more relevant. Others may believe that the naturalness of the life led by the animals is what matters most. Therefore, evaluating animal welfare can be a challenge, since some form of standard is usually necessary for reliable assessment.

A number of animal welfare assessment systems have been developed over the past 30 years, *e.g*. the Animal Needs Index (ANI) and the Freedom Food Scheme. The ANI was developed in Austria and first appeared in a publication in English in 1991 (Bartussek, 1991). It focuses on five husbandry categories: movement and locomotion, social interaction, type and condition of flooring, light and air conditions, and stockmanship (Bartussek *et al*., 2000). The Freedom Food scheme was established by the RSPCA in the UK in 1994 and is based on the "Five Freedoms" proposed by the Farm Animal Welfare Council (FAWC, 1993). According to these "Five Freedoms", animal welfare is guaranteed when:

- The animal is free from hunger, thirst and malnutrition.
- The animal is free from physical and thermal discomfort.
- The animal is free from pain, injury and disease.
- The animal is free to express most of its normal behaviour patterns.
- The animal is free from fear or distress.

A widely used system in recent years is the European Union (EU)- funded Welfare Quality® protocols. Predominantly animal-based, the Welfare Quality® project aimed to integrate four basic areas of concern, denominated as the principles 'good feeding', 'good housing', 'good health', and 'appropriate behaviour'. The protocols are designed specifically with the objective of identifying strengths and weaknesses in animal husbandry and developing strategies to improve animal welfare (Blokhuis, 2008). Protocols have been developed for welfare assessment of cattle, poultry and pigs in production, and have been widely used in research (*e.g*. Tarazona Morales *et al*., 2017; De Graaf *et al*., 2018; Wagner *et al*., 2018). The Welfare Quality® protocols combine indicators for necessities, infrastructure, health and behaviour.

The use of standardised and scientifically accepted protocols has ultimately led to more reliable certification, better opportunities for labelling and marketing schemes, and integration of minimum welfare standards for exports (Ellis and Keane, 2008). However, as the original animal welfare concerns mainly related to conditions in industrialised intensive farming, the emerging assessment protocols were designed for such enterprises, overlooking more traditional systems that work under other conditions and deal with different animal welfare challenges. This is especially true for extensive and pasture-based systems and small-scale traditional farming in developing countries, where the existing protocols may not be applicable due to differences in small-scale production characteristics and some adaptations may be needed.

There have been a few attempts to adapt the Welfare Quality® protocols to the conditions prevailing in year-around extensive systems (*e.g*. Franchi *et al*., 2014; Kaurivi *et al.*, 2019). However, no formal protocol or standard focusing on the necessities and dealing with the welfare issues in these types of systems has been produced to date.

2.3 Tropical countries

Aristotle divided the world into three zones: the frigid zone, the temperate zone and the torrid zone, and stated that humans could only live and work productively in the temperate zone. More than 2000 years later, the tropics are still sometimes viewed as either a place of poverty and pestilence, or a paradise (State of the Tropics, 2020).

When studying the tropics, it is important to determine which countries should be included in the analysis. A tropical country is defined as any nation that lies between the Tropic of Cancer, the parallel of latitude at 23º North, and the Tropic of Capricorn, the parallel of latitude at 23º South. At the very centre lies the equator, equidistant from the North and South Poles, partitioning the globe into two (Figure 1).

A large proportion of the world's land mass lies within the tropics and only the European continent is fully outside the boundaries of the tropics. In America, tropical countries include Mexico, all of Central America, all of the Caribbean islands and the top half of South America, including

Colombia, Ecuador, Peru, Bolivia, Venezuela, Guyana, Suriname, French Guiana and the northern portions of Chile, Argentina, Paraguay and Brazil. Almost all African countries lie fully or partly in the tropics and the only nations that cannot be called tropical countries are Morocco and Tunisia in the north and Lesotho and Swaziland in the south. In Asia, the Middle East has four tropical countries: Yemen, which is entirely in the tropics, and parts of Saudi Arabia, Oman, and United Arab Emirates. In southern Asia, the majority of India is situated in the tropics, and all nations of Southeast Asia are tropical countries. In Oceania, Australia, Micronesia, the Marshall Islands, Kiribati and most of the other islands in the South Pacific are tropical countries.

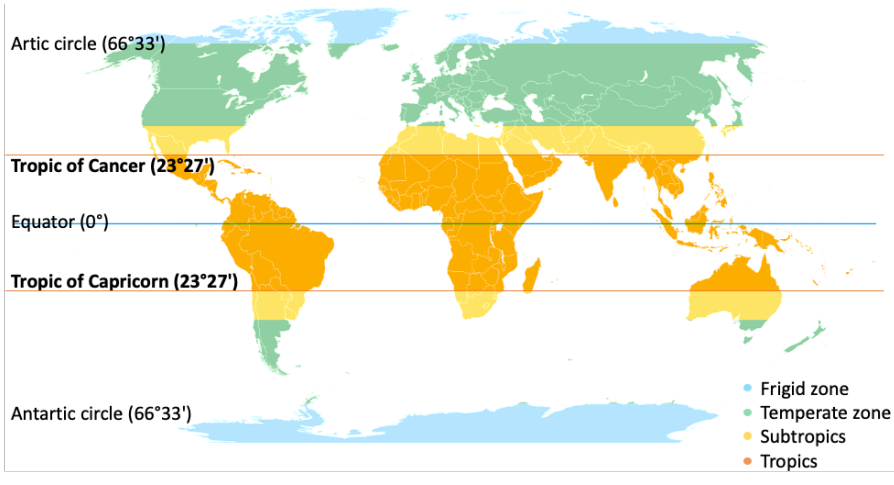

Figure 1. Map of the world depicting the four distinct climate zones: frigid zone, temperate zone, subtropics and tropics (central orange band). (Illustration: Adalinda Hernández)

Together, the tropical countries represent around 40% of the world's land mass and are home to around 40% of the world's population. However, the latter proportion is continuing to increase, and it is estimated that 50% of the world's population and close to 60% of the world's children will reside in the tropics by 2050 (State of the Tropics, 2020).

2.3.1 Climate of the tropics

The temperature in the tropics is more stable and constant than in other areas of the world. This is because all land surfaces in the tropics are struck perpendicularly by the sun's rays at noon on a minimum of one day per year (Feeley & Stroud, 2018). Due to the proximity to the equator, this does not vary much during the year, creating constantly warm weather. Most of the tropics have a dry season and a wet season when most of the annual rainfall occurs. However, not all nations located in the tropics have a tropical climate. Regions including the Sahara Desert and Australian outback, both of which are located within the tropics, are classified as 'dry'. Ecosystems in tropical countries are very diverse, including tropical rainforests, dry forests and deserts (Figure 2).

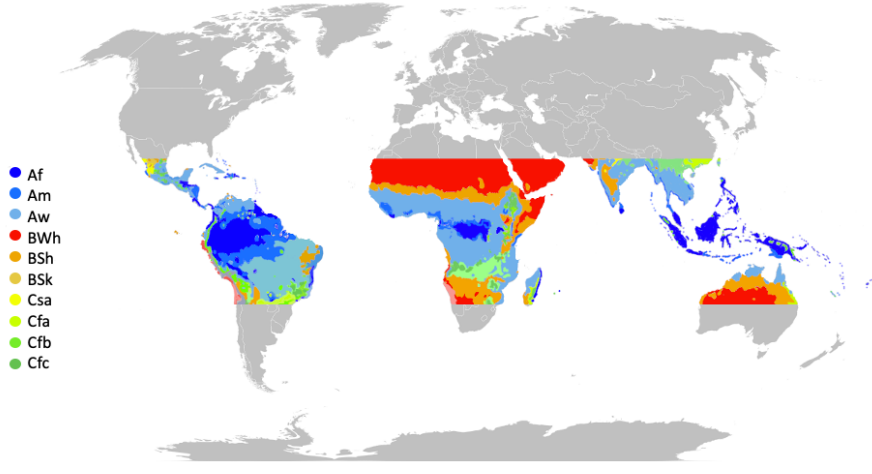

Figure 2. Map of climate zones found in the tropics according to the Köppen-Geiger climate classification system: tropical rainforest climate (Af), tropical monsoon climate (Am), tropical savannah climate (Aw), hot desert climate (BWh), hot semi-arid climate (BSh), cold semi-arid climate (BSk), hot-summer Mediterranean climate (Csa), hot subtropical climate (Cfa), oceanic climate (Cfb) and subpolar oceanic climate (Cfc). (Illustration: Adalinda Hernández).

2.3.2 Socio-economic aspects of the tropics

The countries and people of the tropics are very diverse, but they also share many similar challenges and opportunities. This region has long carried the burden of poverty, more so than in other geographical zones, as a result of complex interactions of factors both within and outside the region (State of

the Tropics, 2020). In recent years, improvements in different factors have slowly been closing the poverty gap (Hemingway, 2014). However, poverty and inequality are still present in the region, with health, nutrition and education deficiencies still widespread among its inhabitants (State of the Tropics, 2020).

Most tropical countries are listed as developing economies by the United Nations (UN, 2020). According to the Food and Agriculture Organization of the United Nations (FAO, 2009), agricultural production must increase by almost 100% in developing countries so that they can supply their rapidly growing population, which is estimated to reach 9 billion people by 2050.

As in non-tropical countries, most agricultural production in tropical countries is performed in rural areas which, as in the rest of the world, are currently being affected by a rapid transition to urban living. The proportion of the population living in cities in tropical countries increased from 31% to 45% between 1980 and 2010, although the proportion is still lower than in non-tropical regions, where around 56% of the population now lives in urban areas (State of the Tropics, 2020). This ongoing migration from rural to urban areas carries the risk of abandonment of the primary agricultural production sector and compromises the objective of meeting the necessary increase in agricultural production.

According to the International Fund for Agricultural Development (IFAD), the average age of farming household heads in developing countries is 49, while the average age of non-household head individuals working on their family farm is 34. However, this average age is becoming higher in some countries, such as Mexico, Peru and Nigeria, where the average age of farming household heads is 53 years (IFAD 2019).

2.4 Cattle production in the tropics

On a global scale, livestock production in the tropics dominates, with a greater number of animals, total output and number of beneficiaries than in non-tropical regions (Oosting *et al*., 2014). In recent times, animal production in the tropics has become a relevant topic due to numerous factors. The most important of these are the increasing demand for animal products in developing countries (FAO, 2009), the impact of livestock production in the tropics on greenhouse gas emissions (de Vries & de Boer,

2009; Gerber *et al*., 2011; Herrero *et al*., 2011) and the potential contribution to alleviating poverty by farming in the tropics (World Bank, 2009; Herrero *et al*., 2013).

There are some major challenges in livestock production in the tropics. For example, production levels are lower than in most temperate parts of the world, as the farms are smaller and achieve lower yields of milk and meat. In addition, most farmers live in poverty and have difficulties marketing their products. Major cities can be far from their farms and, as their production level and budget are low, they have few possibilities to invest in genetic improvements or infrastructure to facilitate storage and transport.

2.4.1 Types of cattle production systems

Production of beef and milk in most countries in the tropics has transformed over time into more intensive systems with a high concentration of animals in smaller areas. However, despite this tendency, traditional systems for dual-purpose cattle continue to provide a livelihood for numerous subsistence farms, even though they lack infrastructure and sound production results. According to the FAO, there are over 500 million family farms in the world, and they make up over 98% of farm holdings. They produce at least 56% of all agricultural production, on 56% of the land (FAO, 2014). In the tropics, these enterprises produce around 41% of the total milk and 50% of beef in the region (FAO, 2014).

In general, agricultural and livestock systems in the tropics are dependent on the actual geographical zone and local climate conditions, as these characteristics limit the available resources.

Temperate tropical zones

The temperate zones in the tropics are generally either on a plateau, usually located around 2000 m above sea level, or on the slopes of mountains. There is reasonable availability of water resources in these zones but, as in most tropical areas, there is a clear distinction between a dry and a rainy season. Cattle in these zones are usually animals dedicated to milk production, generally Holsteins (Kino *et al.,* 2019). A common feature of these farms is the use of pasture as the main source of fodder, supplemented with concentrates, in dairy units rarely larger than 200 head. As the mild climate

allows the use of specialist breeds in intensive systems, zero-grazing units are not uncommon in the temperate zone.

Beef cattle farming in the temperate tropics is also of an intensive nature. However, the dominant type of beef production is the breeding stock, where the animals are raised under extensive pastoral conditions. Animal welfare in this type of unit has already been studied and some welfare risks have been identified. For example, a study in Northern Australia suggested that significant improvements to animal welfare could be made very quickly with a few straightforward management changes (Petherick, 2005). These changes include improved planning for extended dry periods and drought; greater use of conservative stocking rates and supplementary feeding; broader implementation of vaccination programmes; and greater implementation of weaner training programmes (Petherick, 2005). Latawiec *et al*. (2014) reviewed the situation of cattle raised in Brazil under pasture conditions and concluded that improving cultivated pastureland from meeting 32% to almost 50% of its potential would meet current demands until at least 2040, without further conversion of natural ecosystems.

Lowland tropical zones

In general, the lowland tropics can be divided into two types: low humid areas located near the coastline, with mean annual rainfall of 1000-3000 mm per year, and lowland dry tropics, characterised by around 600 mm of annual rainfall, usually occurring in a short part of the season.

Despite the precipitation difference between the two lowland tropics types, cattle production in these zones is performed similarly. Feedlots with steers, or even young heifers, can be found. The feedlot beef fattening system has been criticised by animal welfare societies and entities alike, as an example of maltreating animals in their final stages of their life. Nardone *et al.* (2010) pointed out that finishing calves in a feedlot usually involves transporting them from their native pasture and perhaps selling them through an auction, before arriving at the feedlot. Transport takes a physical and psychological toll on animals, as do unfamiliar surroundings, noise, social regrouping, loading and unloading, and feed and water deprivation. Ndou *et al*. (2011) reviewed animal welfare policies in Africa and concluded that this policy area is still a low priority due to factors such as traditional customs and beliefs, and lack of knowledge on animal handling, housing facilities and

transport. This is further complicated by the fact that cattle are used for multiple purposes, such as production of meat, milk or both, draught power and traditional ceremonies. These welfare issues demand attention.

In the lowland tropics, production under pasture systems has dominated in the past. With technological advances reaching the area, proper extensive systems, where fattening steers are kept under pastoral conditions to provide for the increasing demand for beef raised under grazing settings, have become more common. Within the extensive pastoral production systems in the tropics, there are other subdivisions depending on the type of feed provided to the animals.

The most common extensive production system is based on monoculture of grass species, as the main or only food provided to cattle (Quero *et al*., 2015). These extensive systems can have improved pastures or native pastures, where the nutritional quality of pasture mostly depends on the season (Kubkomawa *et al*., 2014; Muñóz-Gonzalez, 2016). The use of improved pastures has an added advantage that the introduction of exotic species of grass may increase the quantity and quality of fodder available to the animals. For example, in Brazil, probably the largest exporter of beef in the world, less than 10% of fattening animals are kept in feedlots (Jank *et al*., 2014). However, as the demand for beef raised under pasture conditions increases, in the hope of improving animal welfare, another problem arises: How heavily do these systems depend on fertilisers and pesticides?

Improving pastures admittedly increases animal nutrition and probably animal health, but the economics of improving pastures are not attractive enough under the prevailing conditions of the tropics. Moreover, as pointed out by Sere *et al.* (1995), pasture improvements can only play a limited role in improving beef production. To create large-scale mixed farming systems, it would be necessary to introduce new road infrastructure and new technologies, together with establishment of improved pastures.

Dual-purpose cattle production

On pasture-based farms, probably the prevailing system in the tropics is dual-purpose cattle production. These farms differ greatly depending on climate, geographical conditions and socio-cultural factors (Gómez *et al*., 2002; Magaña *et al*., 2006). However, in general, dual-purpose refers to those enterprises where the production objective has not been intensified to

produce either milk or beef, but rather seasonal or constant production of both. In the tropics, dual-purpose farms can have several different objectives, from primarily milk production and the use of male calves and old cows for beef consumption, to mainly beef production and milking only for local or family consumption. These farms are typically family-run, which means that the whole family acts as the workforce in the enterprise and, in many cases, it is the main or sole source of income for the family.

The dual-purpose system is generally most suitable for the tropics and has been developed to suit the region (Rojo-Rubio *et al*., 2008). It predominantly uses zebu cattle (*Bos indicus*). Some areas use crossbreeds with *Bos indicus* as the maternal line and Western breeds of European cattle (*Bos taurus*), such as Brown Swiss, Holstein, Jersey or Simmental, as the sire, in order to improve production. However, most farms do not follow a strict scheme for crossing, and it is common to observe animals with different proportions of each breed of cattle.

2.5 Animal welfare of cattle in the tropics and links to the United Nations sustainable development goals

There is increasing demand for meat world-wide, as the standard of living has improved in many countries and as modern trade agreements, in combination with the ongoing globalisation of farming, have increased the accessibility of animal products globally. The population in developing countries is continuing to grow (Thornton, 2010) and some of these countries are experiencing economic growth, which allows people to include a greater amount of animal products in their diet (Delgado *et al*., 1999). Beef production in the tropics has therefore increased over recent decades, to supply both national and international consumption. It is important for the marketing of animal products that they comply with the demands of consumers and animal welfare organisations. Hence, animal products must be accompanied by quality information, not only on product excellence but also on production values, including facts about the welfare of the animals. Consequently, the livestock industry urgently needs to carry out research on emerging animal-based production systems, such as those in tropical areas of the world (Herrero *et al*., 2010). The concept of sustainability nowadays

covers not only the livelihood of the producers, but also environmental aspects such as climate and biodiversity, and animal welfare.

In 2016, the United Nations Committee on World Food Security published its "Proposed draft recommendations on sustainable agricultural development for food security and nutrition including the role of livestock" (UN, 2016). Recommendation D of Article VIII, entitled "Animal health and welfare" states the need to:

Improve animal welfare delivering on the five freedoms and related OIE standards and principles, including through capacity building programs, and supporting voluntary actions in the livestock sector to improve animal welfare.

Therefore, increasing food animal production does not simply involve increasing the numbers of livestock or livestock herds to meet consumer demands, but rather working with existing herds to be more efficient, without jeopardising animal welfare. By applying adequate animal welfare measures, a decrease in cattle morbidity and mortality can be achieved. If animal welfare is perceived as good, consumers may show an interest in buying animal products in the future. Hence, improved animal welfare is of considerable sustainability relevance.

The UN World Commission on Environment and Development in its report '*Our Common Future*', published in 1987, defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Keeling *et al*. (2019) reformulated this to state that sustainable development aims to balance the different needs of the present, including the achievement of dignity, peace and prosperity, against the challenges that environmental, social and economic limitations represent in our society.

Animal productivity is closely related to animal health and welfare, and thus adequate animal welfare can impact directly or indirectly on several factors affecting the achievement of sustainability, such as poverty and gender inequality, as often women care for livestock on farms in developing countries (Keeling *et al*., 2019). However, linking animal welfare to

sustainable development is not straightforward, as it can partly clash with other goals.

In a comprehensive study characterising the geography of animal production systems world-wide, Seré *et al*. (1995) pointed out that what are generically known as 'tropical conditions' can comprise a wide range of conditions. This indicates that production systems in the tropics can be as variable as the geographical locations in which the animals are kept. However, apart from selective examples of certain regions in the tropics, the clear majority of dairy, beef and dual-purpose cattle on farms in the tropics are raised in extensive systems or under pasture conditions. Another factor affecting farms in the tropics is their capacity to invest. Galina *et al*. (2016) divided farmers into subsistence farmers, medium-income farmers and farmers with a sound budget. The welfare status of these different types of farmers, and the environmental impact of their production, affects the quality of the products in the eyes of society. This in turn can lead to suitable commercialisation and acceptance of the products by the public.

The use of pesticides or fertilisers in production raises great concern about how these can affect water quality and cause depletion of natural bacteria, both elements essential for the quality of the soil. Therefore, finding alternative production systems with a reduced environmental impact is of major relevance. One such alternative can be the silvopastoral system, in which edible shrubs and trees are combined with other feedstuffs, usually native grasses, so the animals have a wider variety of food (Nahed-Toral, 2013; Broom, 2013; Amendola *et al*., 2016). Silvopastoral systems are becoming more popular in the tropics, because of the efficient use of space and the potential for sustainable animal production (Tarazona, 2013). However, as pointed out by Latawiec *et al*. (2014), if not designed correctly, the silvopastoral system can result in a negative effect on livestock performance and animals may tend to concentrate in shaded areas, thus causing trampling effects on the soil and possibly compromising animal welfare.

Regardless of the production system and its impact on sustainability, animal welfare can be improved if basic human aspects are covered. Alleviating poverty and providing access to better-quality education for farmers and

people working with farm animals could make a difference, as many of the major challenges to animal welfare are closely related to human perceptions of animals, knowledge of production procedures and cultural aspects. All these could be improved if people were given better opportunities. A clear example is the performance of painful procedures in livestock without the use of any source of pain relief. These procedures, such as dehorning/disbudding, castration, iron branding and tail docking, are commonly performed in most parts of the world. However, the use of analgesics and anaesthetics can be very variable, and the procedures in question are commonly performed without use of these pharmaceuticals (Morisse *et al*., 1995; Fisher *et al*., 1996; Graf & Senn, 1999; Grøndahl-Nielsen *et al*., 1999; González *et al*., 2010). Other important features that can be very variable are the livestock handling facilities and provision of training in performing various procedures. These aspects play an important role in how much pain the animals experience during the procedure, with shortcomings sometimes resulting in traumatic experiences for the animals, affecting animal welfare and the human-animal relationship (Schwartzkopf-Genswein *et al*., 1997).

3. Aims of the Thesis

The main aim of this thesis was to investigate the general animal welfare status of cattle raised under tropical conditions, with the focus on countries in South and Central America, and to identify areas in need of improvement.

Specific aims of the studies described in Papers I-IV were to:

- Examine the need to modify certain aspects of the original Welfare Quality® protocols for dairy and beef cattle, so as to accurately evaluate animal welfare under the conditions prevailing in small community farming in the tropics (Paper I).

- Apply the Welfare Quality® protocol for dairy cattle to evaluate animal welfare on dairy farms in the tropics with intensive (enclosure), semi-intensive (part-enclosure, part-pasture) and extensive (pasture) housing and management systems (Paper II).

- Establish whether indicators related to animal welfare evaluated by the Welfare Quality® protocol are affected by the dry or the rainy season, facilitating choice of season of assessment from a risk-based perspective (Paper III).

- Identify the effects of facial hot-iron branding in heifers and assess whether pharmaceutical interventions for pain control could be beneficial to animal welfare; and evaluate the effects of such pharmaceutical interventions on human-animal interaction and

short- and medium-term production responses, and any negative side-effects (Paper IV).

4. Materials and Methods

Full information and details of materials and methods can be found in Papers I-IV, which are provided as attachments at the end of this thesis.

The study described in Paper I involved adapting the Welfare Quality® protocols for dairy and beef cattle to the production conditions of dual-purpose cattle raised in family farms in the tropics (Mexico). Paper II examined animal welfare assessment on extensive, semi-intensive and intensive dairy farms in the tropics (Costa Rica). Paper III compared the differences between the dry and rainy seasons on animal welfare status of dual-purpose cattle raised on family farms under tropical conditions (Mexico). Paper IV addressed one of the major welfare issues on tropical cattle farms (painful procedures) in a study in Brazil. Three pain control treatments were compared when performing facial iron-branding of young calves and the short- and their long-time effects of these treatments on animal welfare were determined.

The Welfare Quality® protocols, which are used in Papers I-III, are composed of four principles and 11 validated criteria constituted by several measures reflecting the different aspects of the actual welfare of animals (Welfare Quality®, 2009). The principles and criteria are summarised in Table 1.

Table 1. *Animal welfare principles and criteria constituting the Welfare Quality® protocols (Welfare Quality®, 2009).*

Principle	Criteria
Good feeding	Absence of prolonged hunger
	Absence of prolonged thirst
Good housing	Comfort around resting
	Ease of movement
Good health	Absence of injuries
	Absence of disease
	Absence of pain induced by management procedures
Appropriate behaviour	Expression of social behaviours
	Expression of other behaviours
	Good human-animal relationship
	Positive emotional state

4.1 Paper I

The study presented in Paper I was performed in San Pedro Buena Vista, located in the municipality of Villa Corzo in the state of Chiapas, Mexico (15°47'N, 92°29'W). The climate in this region is hot and sub-humid, with summer rainfall and mean annual precipitation of 1247 mm. The study took place during the rainy season, at a maximum temperature of 31 °C and a minimum of 20 °C, and with average humidity of 86% during the day.

4.1.1 Study farms

The Welfare Quality® protocol for dairy cattle was implemented on 34 dual-purpose farms where the main production focus was milk. Only male calves are sold for finishing from these farms, while old cows with low milk production are slaughtered for beef. The size of the farms studied was 40-300 ha and herd size ranged from seven to 90 cows, with approximately two-thirds of the farms having between 15 and 35 cows. Due to the small size of the herds in the study, all animals (*i.e.* not a sub-sample) were observed and a total of 1093 animals were evaluated. The herds were mostly composed of crossbreed animals (*Bos taurus* x *Bos indicus*). The age of the cows varied

from 3 to 10 years. All the farms in the study operated under the same system; cattle kept on pasture and morning milking, during which supplementary feed (chicken manure, ground maize and dry grass) was dispensed on an individual basis via a trough, but without an accurate measurement of the amount provided. After milking, cows were released to pasture for the remainder of the day and night and brought back to the milking parlour on the following morning. Calves were kept together with their mother night and day, but usually separated and left in a paddock near the milking parlour during milking. Most of the farms performed manual milking and the average milk production per cow ranged from 8 to 14 L/day. The total pasture area and the design of the livestock facilities varied greatly between farms, from none to rudimentary with a simply a roof or single walls made from wood and wire, with the capacity for only one cow at a time, or concrete constructions with 5-10 individual stalls (Figure 3). Each farm had its own design and measurements for the construction, but the cows were not brought indoors apart from during milking. Herds tended to include one or two bulls kept with the cows, and these were usually loaned between different farms to prevent inbreeding.

Figure 3. (Left) The simplest form of milking parlour and (right) the most technically advanced parlour found on farms in the study (Paper I).

4.1.2 Welfare assessment

The welfare assessment was performed using the Welfare Quality® protocols for dairy and beef cattle (Welfare Quality®, 2009). Indicators that could be applicable for all-year-around, grazing-based, dual-purpose systems were selected and are fully described in Paper I. The assessment was carried out by continuous observation of the animals for a period of 120 minutes at

pasture. However, due to the prevailing conditions on the farms in this study, several features were evaluated during the milking sessions, when the animals were gathered in the milking parlour and it was feasible to perform the observations at individual level. These observations covered the whole herd, including cows, calves and bulls, when present.

4.1.3 Calculation of scores

Calculation of scores was performed in accordance with the statistics included in the Welfare Quality® protocol (Welfare Quality, 2009). The result is a number from 0 to 100, with farms divided into the four following categories according to their final score in each category: Excellent: 80.1-100; improved: 60.1-80; acceptable: 20.1-60; and not classified: 0-20.

4.2 Paper II

4.2.1 Study farms

The study was carried out on 60 farms in Costa Rica. The selected farms focused on milk production, employing specialist breeds such as Holstein and Jersey. The farms used mechanical milking, and supplementary feeding and additional mineral salts were provided. The average size of the farms was 60±7.7 cows (range 42 to 1480 cows). The farms were divided according to three possible management systems: an extensive system (n=31), a semi-intensive system (n=24) and an intensive system (n=5). All observations were performed by the same trained assessor.

On the extensive farms, the animals spent all day and night at pasture, going to a milking parlour twice a day. Some features varied depending on the farm, but most of the farms had a concrete floor specially for the animals in the milking parlour. At pasture, water points were small and scarce, but larger troughs were provided in the milking parlour. In this type of system, the animals received supplementary feed in the milking parlour.

The semi-intensive farms were characterised by keeping animals indoors, in a loose house, from afternoon milking to morning milking. After the first milking, the cows were released to pasture. During the period indoors, the animals received supplementary feed and mineral salts, and had access to water points. The indoor flooring commonly consisted of sand (Figure 4).

Figure 4. Night pens on a semi-intensive farm in Costa Rica (Paper II).

In the intensive systems, animals were kept indoors during the whole time. Feeding was based on chopped improved grasses and commercial concentrate. Pens had sand flooring, were large enough to allow the animals to walk around and allowed them access to water troughs all the time. The cows were milked twice a day.

4.2.2 Welfare assessment

Animal welfare was assessed using the Welfare Quality® protocol for dairy cattle (Welfare Quality®, 2009). The within-herd sample size of animals to assess was calculated according to the protocol recommendation (depicted in Table 13 of the dairy cow protocol; Welfare Quality®, 2009).

The farms were visited only once, to complete the observational part of the Welfare Quality® protocol, in accordance with the instructions (Welfare Quality®, 2009). The assessment was performed on the adult cows after being milked in the morning. After the assessment, workers were interviewed to obtain information relating to management and health of the animals.

Because of the characteristics of extensive farms (*i.e.* hilly pastures with abundant foliage), some of the observations, such as the clinical examination and the avoidance distance, were performed during milking in a semi-open space (small pens), where animals still had the chance to avoid human intervention if desiring to do so. Behavioural observations were performed

on pasture, since this is where the animals spend most of their time, and hence their behaviours would only be minimally affected by the evaluations. The assessor used binoculars for the pasture-based observations, to minimise any interference with the animals.

The results were analysed using the formulae provided by the National Institute of Agricultural Research (INRA) in France for calculation of the final scores, in accordance with the methods proposed by the Welfare Quality® protocol for dairy cows.

4.2.3 Statistical analysis

Descriptive statistics for continuous variables were used. Central tendency (mean and median) and dispersion of the data (standard deviation) and measures of position (median, minimum and maximum) were calculated for the general farm score and for each criterion. Furthermore, one-way non-parametric analysis of variance (Anova) using the Kruskall-Wallis test was performed for comparisons between groups of farms, in general and by each principle. All tests were carried out at an α value of 0.05, using the SAS 9.4 statistical package.

4.3 Paper III

4.3.1 Study farms

The study involved evaluating 45 dual-purpose family farms at two different locations in Mexico. Twenty-three of the evaluated farms were in the municipality of Villa Corzo, Chiapas (15°47′N, 92°29′W). The climate in this region is hot and sub-humid, with summer rainfall and mean annual precipitation of 1247 mm. The remaining 22 farms were situated in the municipality of Tuxpan, Veracruz (20°57′N, 97°24′W), which has a tropical climate with average summer rainfall of 996 mm.

The studies were carried out during one dry and one wet season. The farms were selected based on willingness to participate and represented approximately 60% of cattle farms in the relevant locations. According to colleagues with local knowledge, participating farms were not categorically different from those that chose not to participate.

The farms mainly focused on milk production, with only male calves sold for finishing and old cows after their last production cycle slaughtered for beef. The herd size ranged from 7 to 90 cows and the size of the farms from 4 to 15 hectares. Herds were mostly composed of crossbred animals (*Bos taurus* x *Bos indicus*).

The farms operated a year-round, full-time pasture system and the animals were only gathered once per day (morning) for milking, which took a maximum of two hours per day. When gathered, the cows were given a supplementary feed consisting of chicken manure, ground maize and dry grass, with a higher amount of supplementary feed during the dry season. After milking, the cows were released to pasture on native grass. The cows stayed on the pasture unsupervised for the rest of the day and night, and the next morning they were returned to the milking parlour. Calves stayed together with the cows during the day and night, as did one or two bulls.

Livestock facilities differed considerably between farms, from no milking parlour to very rudimentary forms with just a roof made of wood and wire, with capacity for one cow at a time, to concrete constructions with 5-10 individual stalls equipped with a milking machine. Deworming and vaccination were routinely performed according to the national programme for disease control. According to the farmers, the farms did not have a herd veterinarian or regular health checks, and only called a veterinarian when a problem arose. Most farms did not have special facilities to quarantine sick animals, but when an animal was sick it was common practice to separate it from the herd and provide medical treatment. No special measures were taken to prevent attacks by predators and other wild animals that could harm or stress the herds, such as cougars, jaguars, rattlesnakes, coyotes and other small felids native to the area. However, none of the farms reported any attacks.

4.3.2 Welfare assessment

The farms were assessed once during the rainy season (July 2016) and once during the dry season (January 2017). No special efforts were made to improve or change the welfare conditions of the animals between the two assessments. The assessments were performed by the same trained observer

for each farm and area, using the Welfare Quality® protocols for dairy and beef cattle (Welfare Quality®, 2009) as described in Paper I.

The assessments were carried out by continuous observation of the animals for a period of 120 minutes on pasture. These observations covered the whole herd, including cows, calves and bulls present. The generally small size of herds in the study meant that all the animals were observed, and no sub-sampling was performed.

Calculation of scores for each criterion and welfare principle was performed according to the calculation model included in the Welfare Quality® protocols. The results for each criterion and each principle were represented by a number from 0 to 100. Finally, the farms were classified into one of the following four categories based on the final score in each principle: Excellent: 80.1-100; improved: 60.1-80; acceptable: 20.1-60; and unclassified: 0-20.

4.3.3 Statistical analysis

Statistical analyses were carried out using Stata 14 (StataCorp LLC, College Station, TX, USA). For comparison between seasons, the non-parametric Wilcoxon-test for matched pairs was used, because the assumption of normality was often not met. Comparison between seasons was made at all levels (*i.e.* for each separate measure, criterion, principle and overall classification).

4.4 Paper IV

4.4.1 Study farms

Data collection was performed on a commercial farm located in Araguaíana, Mato Grosso State, Brazil (15°04’12.4’’S, 51°57’14.9’’W). In compliance with regulations imposed by the Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA, 2016), all heifers on the farm are vaccinated against brucellosis at around 120 days old. All vaccinated animals are marked on the face with a hot iron, with the mark showing the final digit of the year of vaccination (Figure 5).

Figure 5. Facial hot-iron branding of a crossbreed calf in Brazil after vaccination against brucellosis.

In this study, 92 heifers were evaluated, 32 pure Nellore and 60 crossbreeds (Nellore x Aberdeen Angus). At the beginning of the study, all heifers were individually assessed for body condition and health. They were divided into the following four experimental groups by stratified randomisation, with 23 heifers in each:

- Control group (CO), branded in the traditional way, without any procedure to relieve pain.
- Test group 1 (T1), given an anaesthetic block comprising 5 mL combining 75% lidocaine (2%, Xylestesin®, Cristalia) and 25% bupivacaine (0.5%, Neocaína®, Cristalia), both without vasoconstrictor, in the facial area used for branding (superficial temporal nerve).
- Test group 2 (T2), given the same subcutaneous anaesthetic block as in T1, together with a dose of an anti-inflammatory and analgesic drug, meloxicam (2%, Maxicam®, Ourofino), at 0.5 mg/kg intramuscularly 10 minutes before the branding procedure was performed.

- Test group 3 (T3), given only the dose of meloxicam as in T2, 10 minutes before the branding procedure was performed.

Heifers from groups CO and T3 were subjected to a face manipulation simulating the application of local anaesthesia, but without introducing the needle.

4.4.2 Assessment

The heifers were assessed in the squeeze chute on four occasions:

- Baseline (one hour before starting handling procedures for branding)
- Hot-iron branding (during and immediately after branding)
- 5 days after hot-iron branding
- 60 days after hot-iron branding.

To minimise the disturbance to commercial farm routines, the baseline assessments and the assessment immediately after branding were performed on three groups, each on a different day. First, 30 Nellore heifers were assessed, then 30 crossbreeds, and lastly the remaining 32 heifers. Between the baseline and branding, the animals were restrained in the squeeze chute, using the head bail for one minute to administer the drug/s (anaesthetic and/or anti-inflammatory-analgesic). This procedure was carried out by experienced livestock staff on all animals in the study, irrespective of experimental group. The animals were branded 10 minutes after drug administration.

While restrained in the squeeze chute, the animals were weighed and their behaviour was recorded by two cameras, one filming the head of the heifers at a 90° angle and the other the body from above and behind at a 45° angle. The video recordings were used to evaluate five behaviours: body movement, hind leg movement, movement of back/spine, reaction at release, and body response to branding, each of which is explained in detail in Table 3 in Paper IV. They were also used to evaluate 14 facial expressions: Head position, escape reaction, orbital tightening, eye white showing, tension above the eye, eye tightness, third eyelid, tension in the masticatory muscles, tension of the muzzle, opening mouth, swallowing, screaming, grunting, face response to branding (described in Table 4 in Paper IV). In addition to the facial expressions, a qualitative evaluation of the behaviour was performed

using a visual analogue scale (100 cm) with seven terms (calm, fearful, agitated, tense, comfortable, painful and stressed), adapted from the qualitative behaviour assessment (QBA) method (Wemelsfelder *et al*., 2000).

The flight speed was recorded as the animals exited the squeeze chute, using two photoelectric cells and a stopwatch installed in the corridor at the exit of the squeeze chute to record the time that each animal took to walk a distance of 2 m. The velocity of exit was calculated using these values for each heifer (Burrow *et al*., 1988).

The animals were weighted during the four occasions to have recordings of their weight gain over time.

4.4.3 Statistical analyses

All statistical analyses were performed using the software RStudio (version 1.0.143) and an α value of 0.05. All videos were analysed by two observers, with intra-observer reliability assessed using weighted kappa coefficient (function "cohen.kappa" in the R "psych" package) for scores and frequencies. An intraclass correlation coefficient of the kind "agreement" to QBA terms was also applied. Statistical analyses were carried out in two steps:

- Assessment of changes over time (baseline, immediately after branding, 5 days and 60 days after branding). This was carried out separately for each experimental group (CO, T1, T2, T3). Normality was tested with the Shapiro-Wilk test (function "shapiro.test" in the R "stats" package). Flight speed and weight showed a normal distribution, so Anova using mixed linear models for repeated measures (function "lmer" in the R "lme4"; package) was used. For dichotomous variables (eye white showing, third eyelid and grunting), a logistic regression analysis ("glm" function of the "stats" package) was applied. The other variables were found to be non-normally distributed and therefore mixed generalised models for repeated measures (function "glmer" in the R "lme4" package) were used. The models considered sampling time and breeding as fixed effects and heifer as a random effect. The Bonferroni procedure was used as a *post hoc* test to correct the probability value of rejection of the null hypothesis (function "lsmeans" in the R "lsmeans" package).

- Comparisons between experimental groups at the same sampling time. For flight speed and weight, Anova (function “aov” in the R “stats” package) was performed, considering experimental groups and breeding as fixed effects, using a Bonferroni procedure as a *post hoc* test. For the dichotomous variables, logistic regression analysis was performed as described above. Finally, for the non-normal variables, a Kruskal-Wallis test (function “kruskal” in the R “agricolae” package) was carried out.

5. Summary of results

This chapter provided a summary of the results obtained in Papers I-IV. For full details, see the respective paper.

5.1 Paper I

Of the farms assessed, 74% were below the acceptable level for one or more animal welfare criteria. Based on the average score, the farms in the study area reached an acceptable level with respect to each criterion considered in the protocol. 'Absence of prolonged hunger' and 'pain induced by management procedures' represented a major weakness for the dual-purpose farms in the study. 'Ease of movement' and 'expression of other behaviours' obtained the highest scores. 'Good human-animal relationship' also obtained a high score.

The percentage of farms in each classification category (not classified, acceptable, improved, excellent) for the criteria included in the Welfare Quality® protocols is shown in Figure 6.

Three different sources of water were observed (Figure 7): troughs (artificial container intended to provide water to animals), rivers (natural flowing watercourse) and ponds (natural or artificial pit in the ground). Some farms had combinations of two different sources. The Welfare Quality® protocols only assess artificial drinkers, and water quality in these type of drinkers. This can be completely different for a natural water source, an important aspect to take into account.

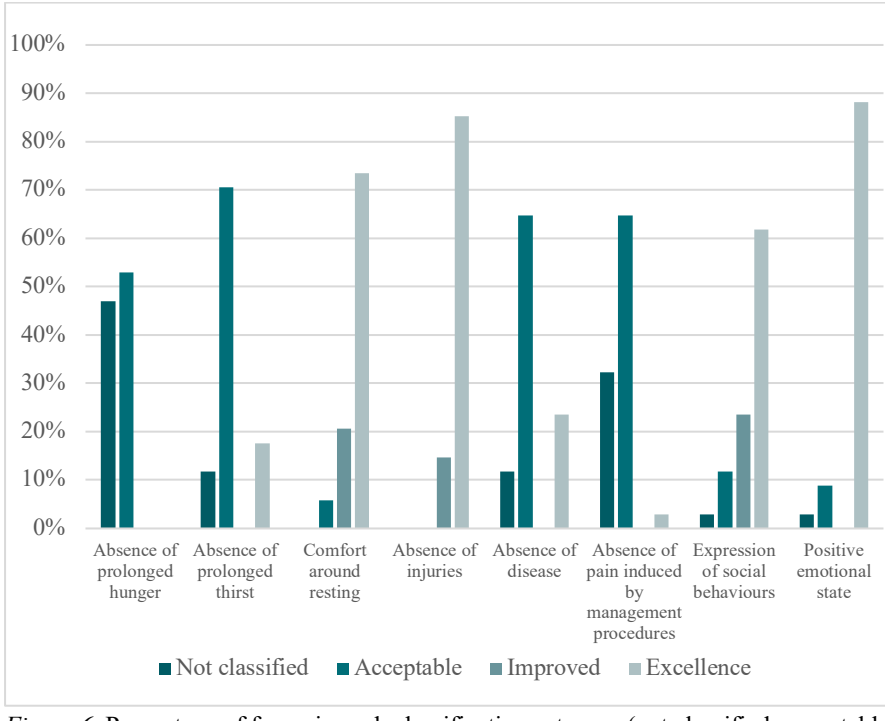

Figure 6. Percentage of farms in each classification category (not classified, acceptable, improved, excellent) for eight of the 11 criteria assessed in the Welfare Quality® protocol. 'Ease of movement', 'expression of other behaviours' and 'good human-animal relationship' are not shown in the graph, since 100% of the farms received scores classified as excellent (Paper I).

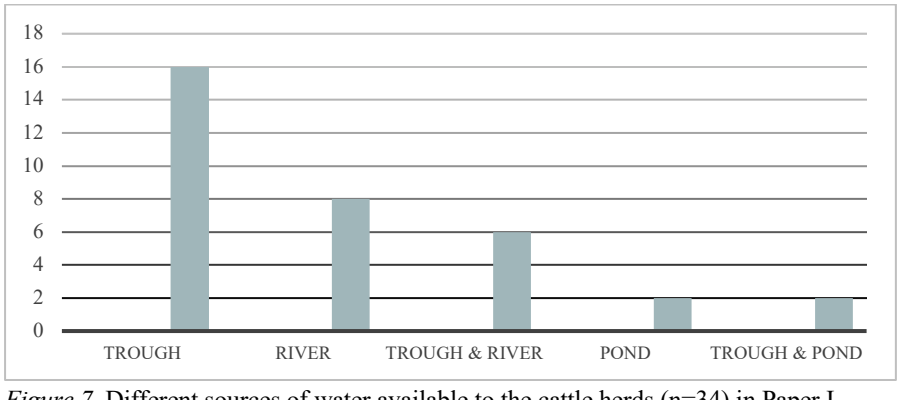

Figure 7. Different sources of water available to the cattle herds (n=34) in Paper I.

5.2 Paper II

The farms in Paper II were grouped according to the management system applied, reflecting common practice in Costa Rica: Intensive (8.3%), semi-intensive (40.0%) and extensive (51.7%). As can be seen in Table 2, none of the groups reached a score of excellent welfare state for three of the four principles of the protocol (good feeding, good health and appropriate behaviour), and only the extensive group achieved the level of excellent welfare state in relation to good housing. The scores related to good health were lower for the three systems and, on average, the farms were above the poor welfare state, but below the neutral level.

Table 2. *Comparison and statistical summary of Welfare Quality® criteria scores by principle for the different types of farming systems in Paper II. Different letters after values within each principle indicate statistically significant differences between management systems ($p<0.05$).*

Principle/ system	**Intensive (n=5)**			**Semi-intensive (n=24)**			**Extensive (n=31)**		
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
Good feeding	69.6a	21.5	75.5	36.0b	21.8	35.6	34.7b	23.3	33.5
Good housing	65.1a	5.2	65.0	79.0b	13.4	77.0	88.6b	11.0	93.3
Good health	38.2a	5.2	39.2	40.0a	7.0	37.7	40.5a	10.5	38.5
Appropriate behaviour	45.8a	7.1	45.1	57.0a	12.7	56.6	56.2a	15.5	59.1

n = Sample size; SD = Standard deviation

The results for the good feeding principle can be seen in Figure 8. None of the production systems reached the excellent welfare state for the criterion 'absence of prolonged hunger', where the extensive farms scored the lowest. For the 'absence of prolonged thirst' criterion, intensive farms scored higher, almost reaching the excellent welfare level; semi-intensive and extensive farms were placed above poor, but below a neutral level of welfare.

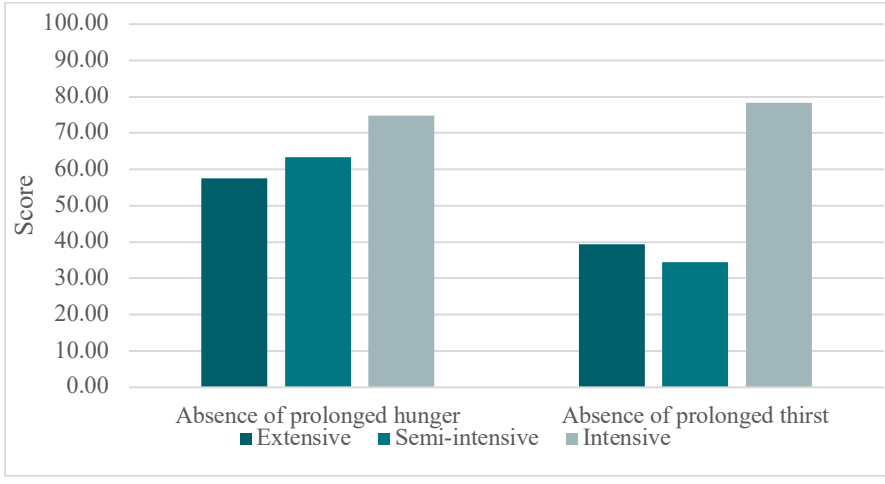

Figure 8. Scores obtained by extensive, semi-intensive and intensive farms for the two relevant criteria, 'absence of prolonged hunger' and 'absence of prolonged thirst', assessing the Welfare Quality® principle of good feeding (Paper II).

The results for the principle of good housing can be seen in Figure 9. Extensive farms scored the highest, reaching an excellent welfare state. Semi-intensive farms achieved a neutral welfare and intensive farms were below the neutral welfare state.

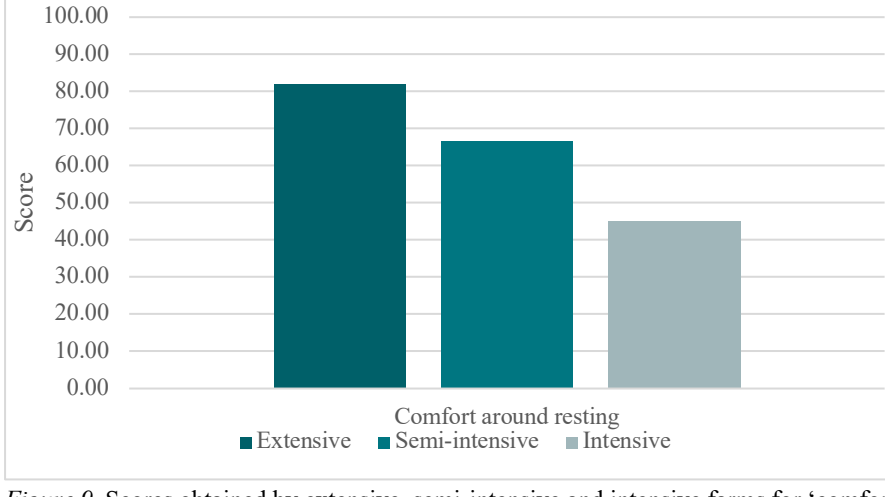

Figure 9. Scores obtained by extensive, semi-intensive and intensive farms for 'comfort around resting'. Ease of movement is excluded since all farms reached the maximum score in this criteria (Paper II).

The results for the principle of good health can be seen in Figure 10. 'Absence of pain induced by management procedures' was one of the main animal welfare risks observed on all three types of farms, due to the lack of anaesthetic and analgesic use. The three groups reached a neutral welfare state for the criteria 'absence of disease' and 'absence of injuries'.

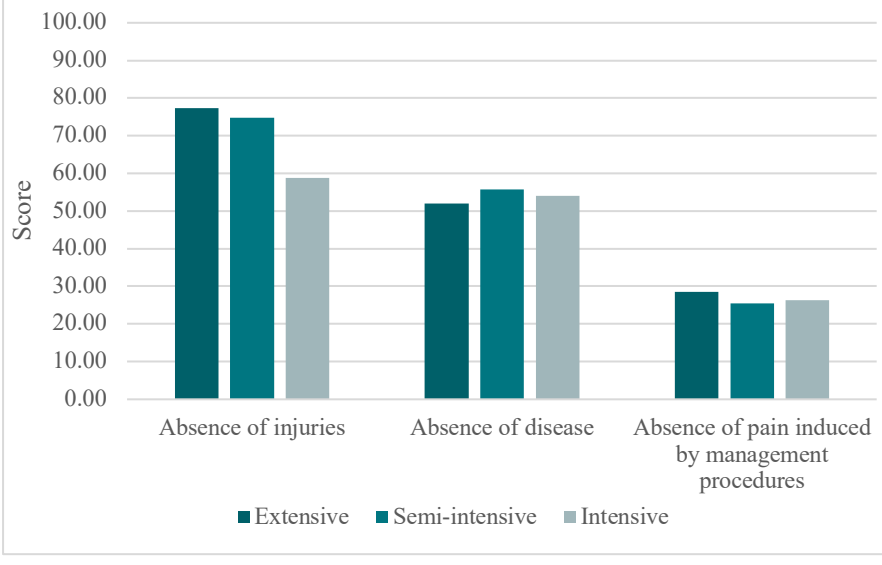

Figure 10. Scores obtained by extensive, semi-intensive and intensive farms for the three relevant criteria, 'absence of injuries', 'absence of disease' and 'absence of pain induced by management procedures', assessing the Welfare Quality® principle of good health (Paper II).

The results for the principle of appropriate behaviour can be seen in Figure 11. All farms were assessed as having an excellent welfare state in 'expression of social behaviour'. For the criterion 'expression of other behaviours', the intensive system scored significantly lower than the other two groups of farms and did not achieve the neutral welfare state. For 'good human-animal relationship', the three types of systems reached the neutral welfare state. The three groups of farms also obtained a neutral level for 'positive emotional state'.

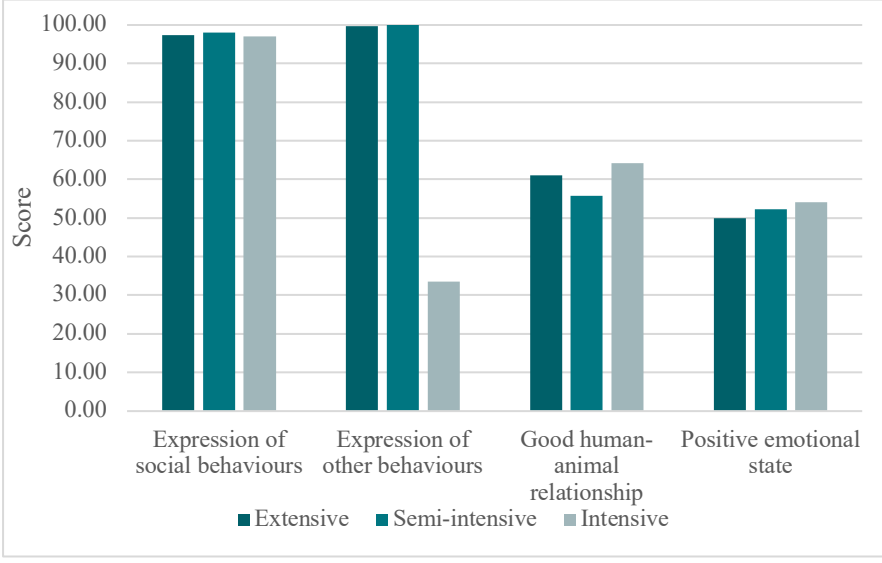

Figure 11. Scores obtained by extensive, semi-intensive and intensive farms for the four relevant criteria, 'expression of social behaviours', 'expression of other behaviours' (assessed as the amount of time the cows spend on pasture), 'good human-animal relationship' and 'positive emotional state', assessing the Welfare Quality® principle of appropriate behaviour (Paper II).

5.3 Paper III

Results of the overall classification of farms in Paper III are presented in Table 3. During the rainy season, four out of the 45 farms studied did not achieve the minimum score to be classified as having an acceptable welfare level, 14 were classified as acceptable, 26 as enhanced and one as excellent. During the dry season, 31 of the farms were classified as having an enhanced welfare level and 14 as excellent (Table 3).

Table 3. *Number and percentage of farms in Paper III falling into the excellent, enhanced, acceptable and non-classified assessment categories according to the Welfare Quality® protocol scores for the rainy season and the wet season.*

Classification of animal welfare	Rainy season		Dry season	
	No. of farms	Percentage	No. of farms	Percentage
Excellent	1	2.2	14	31.1
Enhanced	26	57.8	31	68.9
Acceptable	14	31.1	0	0
Not classified	4	8.9	0	0

The average scores for the four animal welfare principles evaluated (good feeding, good housing, good health and appropriate behaviour) are presented in Table 4.

Table 4. *Calculated scores for animal welfare principles and the relevant criteria in the Welfare Quality® assessment on the 45 farms in Paper III during the rainy season and the dry season.*

Principle	Criteria	Rainy season			Dry season			P-value
		Mean	Min	Max	Mean	Min	Max	
		28.6	**0.2**	**100**	**59.4**	**30.8**	**100**	**<0.001**
Good feeding	Absence of prolonged hunger	32.6	3.8	100	71.8	30.3	100	<0.001
	Absence of prolonged thirst	57.7	0	100	73.1	29.0	100	0.02
		89.5	**40.4**	**100**	**96.0**	**72.1**	**100**	**0.008**
Good housing	Comfort around resting	86.5	23.6	100	94.9	64.2	100	0.003
	Ease of movement[1]	100	100	100	100	100	100	-
		48.3	**9.6**	**100**	**68.7**	**18.4**	**100**	**<0.001**
Good health	Absence of injuries	88.0	43.9	99.7	96.5	61.6	100	0.002
	Absence of disease	52.5	7.3	100	75.5	22.3	100	0.28
	Absence of pain induced by management procedures[2]	29.5	15.7	100	29.5	15.7	100	-
		82.2	**26.0**	**96.1**	**89.1**	**58.7**	**100**	**0.02**
Appropriate behaviour	Expression of social behaviour	81.3	19.0	100	87.2	65.7	100	0.007
	Expression of other behaviours[1]	100	100	100	100	100	100	-
	Good human-animal relationship	93.8	65.4	100	89.6	72.3	100	<0.001
	Positive emotional state	94.8	25.8	100	85.9	17.2	100	<0.001

[1]Kept on pasture during the whole year.

[2]Management of painful procedures did not differ between assessments.

The animals on the farms in Paper III had three different sources of drinking water: troughs, rivers and ponds (Figure 12). Some farms used two different type of sources simultaneously and the availability of different water points also varied between the two seasons. Troughs were the most common source of water supply in both the rainy and dry season. In the rainy season, nine farms used rivers, while only three farms used rivers as the only source of water during the dry season (Figure 12). The combination of troughs and rivers was equally present during both seasons. Ponds were also used more during the rainy season, where one farm used a pond as the main source of water and five farms used ponds in combination with troughs. In the dry season, only four farms used a combination of troughs and ponds.

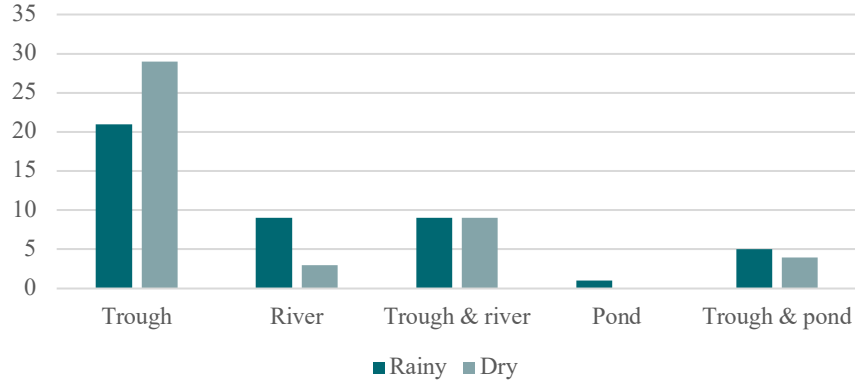

Figure 12. Sources of drinking water for the animals in Paper III (n=45) during the two seasons assessed. Three different sources of water were observed: troughs, rivers and ponds, and two different combinations of these, trough & river and trough & pond.

5.4 Paper IV

As can be seen in Table 5, there were no significant differences in the measured flight speed values (m/s) between observation points or between the treatment groups.

Table 5. *Mean and standard deviation (SD) of flight speed (m/s) over time for each experimental group in Paper IV. (CO = control group; T1 = local anaesthetic; T2 = local anaesthetic + intramuscular analgesic; T3 = intramuscular analgesic*).

Experimental group	Observation point							
	Baseline		Branding		5 days after		60 days after	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CO	1.65 B	0.64	1.82	0.66	1.57	0.67	1.72	0.67
T1	2.05 aAB	0.50	2.01 ab	0.54	1.88 ab	0.64	1.71 b	0.67
T2	2.05 AB	0.51	2.04	0.63	1.85	0.63	2.00	0.52
T3	2.17 A	0.58	2.24	0.47	1.89	0.72	2.14	0.80

Lowercase letters indicate significant difference over time within groups (a>b>c>d) and capital letters indicate significant differences between groups (A>B>C>D).

Weight gain over time showed no significant differences between the experimental groups for a particular observation point (Table 6). However, a significant effect of observation period on weight gain over time was observed for all groups and in the comparison of groups at different observation points (baseline, 5 and 60 days after branding).

Table 6. *Mean and standard deviation (SD) of body weight (kg) over time for each experimental group in Paper IV (CO = control group; T1 = local anaesthetic; T2 = local anaesthetic + intramuscular analgesic; T3 = intramuscular analgesic).*

Experimental group	Observation point					
	Baseline		5 days after		60 days after	
	Mean	SD	Mean	SD	Mean	SD
CO	142.96 c	30.84	147.63 b	32.83	207.15 a	35.84
T1	147.26 b	34.96	152.59 b	36.08	212.78 a	41.56
T2	146.32 b	34.06	150.63 b	35.67	211.72 a	42.24
T3	146.36 c	31.21	150.59 b	33.79	212.38 a	39.79

Lowercase letters indicate significant difference over time within groups (a>b>c>d) and capital letters indicate significant difference between groups (A>B>C>D).

In the CO group, ‘eye tightness’ and ‘opening mouth’ showed a difference over time, the former being lower 60 days after branding and the latter higher during branding. For the other groups, there was no significant difference. ‘Tension of the masticatory muscles’ was higher 5 days after branding for the CO group, scored the lowest during branding for T1 and was similar for groups T2 and T3 at all four observation points.

The variable ‘fearful’ was scored higher during the baseline than at any other observation point for all four groups (Table 7). The median score for ‘tense’ was lower during baseline for CO and T3, but at 5 days after branding the scores were higher than at any other observation point. ’Painful’ was scored higher at branding than at other observation points for all experimental groups (Table 7).

As can be seen in Table 8, the median score for ‘movement’ was higher at the baseline and 60 days after branding for groups CO and T3, at 60 days after branding for the T1 group, and at the baseline and during branding for the T2 group. ‘Tail movement and position’ scored higher during branding in all treatment groups and scored the lowest in the observations at 5 days after branding for CO, T1 and T2. The body response to branding was the same for all treatment groups.

Table 7. *Median and range (minimum - maximum) of qualitative assessment behaviour scores of face view over time for each experimental group in Paper IV (visual analogue scale in cm) (only the variables for which differences were observed are presented). CO = control group; T1 = local anaesthetic; T2 = local anaesthetic + intramuscular analgesic; T3 = intramuscular analgesic.*

	Baseline		Branding		5 days after		60 days after	
Observation point for group CO								
	Median	Range	Median	Range	Median	Range	Median	Range
Fearful	4.2 a	0.5-7.1	2.1 b	0.1-7.5	1.6 b	0.1-5.9	2.4 b	0.1-5.3
Tense	5.6	2.2-9	6.7	1.7-9.1	6.9 A	5-9.7	6.5	2.3-8.9
Comfortable	0.5 a	0.1-4.4	0.2 b	0.1-2.4	0.2 b	0.1-1.4	0.3 ab	0-2.9
Painful	0.2 b	0.1-3.3	4.8 a	1.6-7.7	0.3 b	0.1-2.4	0.1 b	0-1.2
Observation point for group T1								
Fearful	3.5 a	0.2-7.9	1.2 b	0.1-4.1	1.9 ab	0.1-6.3	1.7 b	0.2-6.3
Agitated	2.6 ab	0.1-9.5	1.9 b	0.1-8.8	4A	0.2-8.2	2.9 a	0.1-8.7
Tense	5.6	4-9.3	5.25	3-9	5 B	1.4-7.6	6.2	3.8-8.9
Painful	0.4 b	0.1-3.9	3.1 a	0.8-5.9	0.2 b	0.1-1.6	0.1 b	0-1.8
Observation point for group T2								
Fearful	4.5 a	0.2-7.7	1.4 b	0.2-4.3	1.7 ab	0.1-8.5	1.9 b	0.2-4.7
Tense	6.4	1.7-8.8	5.4	2-9.6	6.3 A	4.2-9.3	6.2	0.3-8.8
Painful	0.2 b	0.1-1.9	4.4 a	1.1-9.4	0.2 b	0.1-1.5	0.1 b	0-1.1
Observation point for group T3								
Agitated	3.9 ab	0.5-7.9	3 b	0.5-9.1	5.3 a	0.1-7.7	3 ab	0.5-8.6
Tense	5.3	2-8.9	6	0.6-9.2	6.5 A	3.1-9.7	6.3	3.2-8.8
Painful	0.2 b	0.1-2.2	3.7 a	2-7.3	0.2 b	0.1-2.8	0.1 b	0-1.2

Lowercase letters indicate significant difference over time within groups (a>b>c>d) and higher letters indicate significant difference between groups (A>B>C>D).

Table 8. *Median and range (minimum - maximum) of behaviour scores over time for each experimental group in Paper IV. CO = control group; T1 = local anaesthetic; T2 = local anaesthetic + intramuscular analgesic; T3 = intramuscular analgesic.*

	Baseline		Branding		5 days after		60 days after	
Observation point for group CO								
	Median	Range	Median	Range	Median	Range	Median	Range
Movement	1 ab	0-3	0	0-3	0	0-3	1	0-3
Tail movement and position	2	0-4	3a	1-4	1	0-4	1	1-3
Body response to branding	--	--	1	0-2	--	--	--	--
Observation point for group T1								
Movement	0b	0-3	0	0-2	0	0-2	1	0-3
Tail movement and position	1	0-3	3	1-4	1	0-3	1 b	1-3
Body response to branding	--	--	1	0-2	--	--	--	--
Observation point for group T2								
Movement	1a	0-4	1	0-3	0	0-3	0	0-4
Tail movement and position	2	1-4	3	1-4	1	0-2	1	1-3
Hind legs movement								
Body response to branding	--	--	1	0-2	--	--	--	--
Observation point for group T3								
Movement	1ab	0-3	0	0-3	0	0-3	1	0-3
Hind legs movement								
Tail movement and position	2	0-3	3a	1-4	2	1-3	2	1-4

Body response to branding	--	--	0	0-2	--	--	--	--

Lowercase letters indicate significant difference over time (a>b>c>d) (only the variables for which differences were observed are presented).

6. General Discussion

The rapid changes in today's society require farmers to know and pay attention to consumer demands on animal welfare, particularly in relation to animals used for human consumption. Therefore, methods for assessing the actual state of farm animal welfare are essential, in order to identify improvements which can help medium- and small-scale producers remain active and increase their farm production, without compromising animal welfare or environmental responsibility. This thesis investigated the general animal welfare status of cattle raised under tropical conditions and practices on farms in developing countries in the tropics that put animal welfare at risk.

6.1 Welfare assessment under tropical conditions

Standardised protocols to assess animal welfare, such as the Welfare Quality® protocols used in Papers I, II and III in this thesis, are primarily designed and created to assess intensive farms in Europe, where the objective is high production levels. These conditions often differ from those in the tropics, where *e.g*. climate conditions, availability of land and resources, and breeds of cattle suitable for the tropics make it more practical to have extensive pasture-based systems. These particular features of cattle raised under tropical conditions generally result in less productive enterprises that are therefore more vulnerable to the changes imposed by a more demanding modern society.

In Paper I, a study in Mexico evaluated whether the Welfare Quality® protocols can be a useful tool for assessing animal welfare in dual-purpose

family systems in the tropics. Some of the differences in farming conditions observed while performing the study were small and easily adjustable, while others represented a greater challenge. First, since the production objective for dual-purpose family farming is both milk and meat production, it was necessary to merge indicators from the Welfare Quality® dairy and beef cattle protocols to adjust them to the conditions on the study farms. However, even after performing those adjustments, some sections of the protocols were found not to be applicable.

6.1.1 Good feeding

One of the main problems in farming under tropical conditions is limited access to clean drinking water. Moreover, the sources of water present can be very different to those found in industrialised farming, as they generally consist of ponds, rivers or streams. Thus, when assessing the Welfare Quality® principle of good feeding, it was difficult to assess whether these sources are sufficient for the herd, which affected the scores for the animal welfare criterion 'absence of prolonged thirst'. However, while performing the studies described in Papers I and III, a shortage or absence of water sources either at pasture or in the milking parlour was often observed. Most farms only had water sources in one area, which resulted in animals spending long periods without drinking water. This can be a potential welfare problem, especially in the hot dry season (Ahmed & El Hag, 2003). However, tropical cattle are usually better adapted to limited access to water and the real impact on animal welfare might need further research.

6.1.2 Good housing

The scoring for the Welfare Quality® principle of good housing was affected by non-applicability of most of the criteria, which did not apply due to the absence of infrastructure on the study farms (*i.e*. no indoor housing). For the farms studied in Papers I and III and the extensive farms in Paper II, the score obtained for this principle was very high, but this might not reflect the true welfare status since an actual feature might not have been evaluated. In order to accurately assess animal welfare, some measures could be replaced by others, *e.g*. 'lying outside the lying area' could be replaced with 'lying in the

shade'. However, it is important to note that this measure was particularly difficult to assess since animals were not observed lying down frequently while on pasture, while those observed lying showed no apparent preference for shady or sunny areas. The results might be different at another time of the day, *e.g*. the hottest time, as indicated by Galina *et al*. (1982) and Orihuela *et al*. (1983), or during the dry season, which is warmer. Therefore, a suggested measure to assess this aspect could be 'access to shade in pasture', regardless of whether the animals are using it at that precise moment. Likewise, the measure 'animals colliding with housing equipment' did not apply to the conditions prevailing in the study area. A suggested approach is to assess the stocking density, *i.e*. the number of animals/m^2, in the area where the cows are kept during the night and the site for milking, *i.e*. the area around the milking parlour (Waiblinger *et al*., 2001; Schneider, 2010).

6.1.3 Good health

The lack of production records kept by the farmers included in Papers I and III represented a challenge when assessing the Welfare Quality® principle of 'good health', especially the criteria relating to mortality. It is important to note that when mortality was reported, the most common cause of death cited was an accident rather than disease. However, this aspect warrants further investigations.

Farms in the tropics can show significant variation in herd size, as seen in Papers I-III. When assessment measures based on percentages, *e.g*. health-related problems and disease incidence, are carried out on a low number of animals, their influence on the total score given to that farm is very large, since one single animal will constitute a significant proportion of a small herd, but without stating that the whole herd is affected or at risk. It is notable that herd size can also affect the approach and potential usefulness of the Welfare Quality® protocols in an extensive system. The difficulties and limitations observed in this thesis differed from those reported by Huertas *et al*. (2009), who applied the same protocols on larger extensive farms in Latin America.

The Welfare Quality® protocol for dairy cows assesses the presence of mastitis in serial testing using the California Mastitis Test. This procedure

could not be applied to the farms in Papers I and III, as the rustic units studied lacked adequate infrastructure, *i.e*. access to clean water for proper sanitation and prevent cross contamination. Instead, aspects such as udder hygiene at milking can be taken into consideration for a more adequate assessment. On the study farms, 'udder hygiene' usually consists of the calf suckling before and after the cow is milked (Das *et al*., 2001), and there was no evidence of clinical mastitis on the study farms. Data obtained by Fröberg *et al*. (2007, 2008) in studies on dual-purpose cattle in the tropics show that calf suckling improves udder health and that the relatively low level of milk production in these herds most likely contributes to a low incidence of mastitis.

6.1.4 Appropriate behaviour

Social interaction was rather low among the animals studied in Papers I and III, which could be due to the greater availability of space in pasture-based systems. This was a difficulty when assessing the Welfare Quality® principle of appropriate behaviour. This was not a difficulty on the extensive farms in Paper II, where the animals had similar conditions and access to space as in Papers I and III. However, calves and bulls were kept with the cows on the farms in Papers I and III, which could serve as a distraction, and interactions with these animal groups should also be considered during the assessment. During the studies reported in Papers I and III, interactions with other types of animals apart from adult cows, including calves and bulls and occasionally other species such as horses, poultry and wild fauna, were commonly observed. Hence, the importance of these events should be taken in consideration when assessing this type of farm, to obtain more information about the expression of social behaviour (Masahiko *et al*., 2013).

The animals studied on farms included in Papers I and III and on the extensive farms in Paper II were kept in large open spaces and were easily able to avoid people touching them if desired, without necessarily being afraid. Therefore, the criterion 'good human-animal relationship' also represented a challenge when attempting to assess the appropriate behaviour aspect of animal welfare with good accuracy.

6.2 Tropical pasture life: Advantage or disadvantage for animal welfare?

While keeping cattle in a complete pasture-based system might seem natural and, in general, pose fewer risks to cattle welfare than indoor housing systems, in reality they are often insufficient empirical data to confirm this. The main findings on the animal welfare advantages or disadvantages of the farming systems studied in Papers I-III are discussed below.

6.2.1 Good feeding

Most of the farms included in Papers I and III are dependent on native pastures where the nutritional content of the herbage can be rather poor. This was reflected in the results for the criterion 'absence of prolonged hunger' presented in this thesis, where extensive farms obtained a lower score than semi-intensive and intensive systems in which the pasture typically consisted of more specialised non-native grasses. In addition, most of animals on farms studied in Papers I and III, and on the extensive farms in Paper II, lacked access to supplementary feed. However, it is important to consider that the physical activity in searching for fodder might represent a higher use of energy, but probably does not reflect prolonged hunger.

The seasonal differences that occur in the tropics are slight compared with those in non-tropical areas, but may affect the cycle of pasture, changing the quantity and quality and causing variations in the body condition of the animals from one season to another. It has been observed that, during the dry season, animals in the tropics can lose more that 10% of their live weight (Winks, 1984). However, in Paper III, which compared animal welfare during the rainy and dry seasons, this effect was not observed. This could be explained by the predominance in that study of animals with tropical cattle genes that are better adapted to the effects of poor nutrition than European breeds (Frisch & Vercoe, 1984; Petherick, 2005). Further, during the dry season, when the availability of food at pasture is lower (Humphreys, 1991), the animals often received supplementary feeding in higher quantities. Most tropical grasses are not sufficient in nitrogen content (Tarazona Morales *et al*., 2017), so receiving a larger portion of supplementary feed could fulfil

the nitrogen requirement of the animals, resulting in a better body condition score during the dry season.

The Welfare Quality® protocols consider water intake to be associated with the number and size of water points available for the animals. In Paper II, extensive and semi-intensive farms scored considerably lower than intensive farms for the criterion 'absence of prolonged thirst'. Providing good quality water might be easier in an enclosure than on pasture, where a supply of clean, good quality water may be difficult to maintain. In addition, alternative sources of water, such as rivers, ponds and streams, lack an official assessment criterion in the Welfare Quality® protocols, affecting the scores for pasture-based farms. Water intake is also affected by other features, such as climate and diet (Dahlborn *et al*., 1998; Meyer *et al*., 2004). Consequently, basing the assessment exclusively on the number of water points is questionable, although such simplifications of course improve the feasibility of the protocols (de Vries, 2013).

As mentioned, pasture-based systems in Papers I-III used natural sources of water, which depend directly on the amount of rain. In Paper III, these sources were larger and more frequently observed on farms during the rainy season than during the dry season. During the time that no natural source of water was available for the animals, troughs were provided in the pasture area. These troughs were usually cleaner and easier to measure with the Welfare Quality® protocol, resulting in higher scores for this criterion during the dry season. These higher scores are significant, since tropical cattle (*Bos indicus*) need around 10 L of water per kg dry matter consumed (CSIRO, 2007), and therefore good water sources are more relevant for animal welfare during the dry season.

6.2.2 Good housing

The general absence of housing infrastructure on pasture-based farms in the tropics resulted in very high scores for the principle of good housing for farms in Papers I and III and for extensive farms in Paper II. The extensive farms in Paper II obtained the highest score, reaching the excellence level for the criterion 'comfort around resting', while semi-intensive farms scored slightly lower and intensive farms obtained the lowest results. In Paper III, the same criterion obtained poorer scores during the rainy season. The results

were mainly influenced by the average time spent lying down, where the muddy slippery surfaces created by rain during this period made this more difficult for most animals. It is known that cattle rest and ruminate while lying down, indicating the importance of this behaviour (Munksgaard & Simonsen, 1996).

However, based on the results and observations in Papers I-III studies, it is not possible to conclude that extensive and semi-intensive farms have necessarily better welfare status in terms of this principle. The Welfare Quality® protocols are designed to assess only intensive farms, so the results for extensive and semi-intensive systems could be biased. Therefore, further studies are necessary.

6.2.3 Good health

It has been observed that a pasture-based system has lower levels of diseases such as lameness (Hernandez-Mendo *et al*., 2007; Olmos *et al*., 2009) and mastitis (Bendixen *et al*., 1988; White *et al*., 2002; Washbum *et al*., 2002). This was confirmed by the findings in Papers I-III. In addition, intensive systems with access to pasture have a lower incidence of hock lesions (Rutherford *et al*., 2008; Potterton *et al*., 2011; Burow *et al*., 2013), which are usually caused by the animals lying down on abrasive surfaces or colliding with infrastructure (Kester *et al*., 2014). Such lesions are not commonly seen in pasture-based systems.

However, on most of the farms in Papers I-III, the principle of good health was negatively affected by the common practice of performing painful procedures, including disbudding and dehorning, without anaesthetic or analgesic. Therefore, failure to meet the criterion 'absence of pain induced by management procedures' was one of the main problems observed. In some cases where the scores fell within the limits considered acceptable, this may not be a reflection of well-performed practices, but rather the complete absence of some practices evaluated in the protocol, such as tail docking and castration. Some other practices that were commonly performed, and which could also negatively influence animal wellbeing, are not taken into account in the Welfare Quality® protocols (*e.g.* iron branding and ear-tagging). Hot-iron branding may inflict similar pain to disbudding with a hot iron, since both interventions involve very similar equipment, duration of the

intervention and physical reactions in calves. In fact, Millman (2013) reported a greater number of vocalisations during branding than during disbudding or castration. This is a very important aspect, since there is evidence that animal pain has a very high impact on their welfare (Fraser, 2008). Moreover, the absence of a livestock crush or any other structure designed for performing these procedures, or other common procedures such as deworming or vaccination, could be major causes of stress (Orihuela & Solano, 1994).

Contrary to popular beliefs about the health benefits a pasture-based system may have for cattle, several epidemiological studies have shown that grazing increases the exposure to gastrointestinal parasites (Charlier *et al*., 2005; Forbes *et al*., 2008; Bennema *et al*., 2010). The negative impact of gastrointestinal parasites has been demonstrated in several studies, which also show a positive response to anthelmintic treatments in adult cows, in terms of production, body condition score and reproductive performance (Sanchez *et al*., 2004; Forbes *et al*., 2004; Gibb *et al*., 2005). This indicates the necessity for adequate parasite control protocols in pasture-based systems. Internal parasite burden is not covered by the Welfare Quality® protocols.

6.2.4 Appropriate behaviour

No relevant differences between systems regarding the principle of appropriate behaviour were found in Paper II. All farms obtained high scores for 'expression of social behaviour', regardless of the management system, as it was assessed in their common environment (pasture in extensive farms and pens in semi-intensive and intensive farms). The only difference was observed for the criterion 'expression of other behaviours', measured as the time the animals spend on pasture. This characteristic was only suitable for evaluating intensive farms, and not necessarily extensive systems where animals are kept free all the time. Future actions to assess this variable should bear this in mind, since free grazing year-round is still very common on farms in developing countries (Nicholson *et al*., 1994; González-García *et al*., 2012). Regarding 'good human-animal relationship', all farms in Paper II scored the minimum level to be in a neutral welfare state. Extensive farms

scored higher than semi-intensive systems farms, which could indicate that although extensively reared animals have less contact with humans through being on the pasture all day, this does not have any negative effect on their interaction with humans. This was in accordance with findings in Papers I and III. Nevertheless, there is plenty of evidence that human-animal interactions in intensive systems can affect animal welfare and productivity (Hemsworth, 2003; Raussi, 2003), but the evidence of similar effects in extensive systems is limited (Petherick, 2005). In addition, temperament of cattle may also play an important role, especially when assessing herds of tropical cattle. Several studies have demonstrated that temperament, measured by flight speed, plays a major factor related to the productivity of the animals (Voisinet *et al*., 1997; Fell *et al*., 1999; Petherick *et al*., 2002) and may also affect their welfare (Petherick *et al*., 2002).

6.3 Painful procedures

One of the major welfare issues observed in Papers I-III was the use of painful procedures, especially when performed without any pain control. These practices can lead to traumatic experiences for the animals, generating fear and consequently leading to changes in the behaviour that can negatively impact the human-animal relationship (Schwartzkopf-Genswein *et al*., 1997). Paper IV investigated the effects of facial hot-iron branding on heifers and assessed whether the use of pain relief, such as local anaesthesia and/or post-procedure analgesia, could be beneficial to animal welfare and diminish the negative effects on human-animal interaction and short- and medium-term production responses.

6.3.1 Assessment of pain

Pain can be difficult to assess due to its subjective nature, but previous studies have shown that behaviour can be a useful indicator of pain (Anil *et al*., 2002; Cuttance *et al*., 2019). However, no clear behavioural differences between the groups at branding were observed in Paper IV. This could be due to a possible similarity in the expression of acute pain and psychological stress (fear) caused by the entire herding and restraining situation. In

previous studies, handling and restraint has been suggested to act as an interference when measuring acute pain responses in cattle (Lay *et al*., 1992; Schwartzkopf-Genswein *et al*., 1997). Thus, it could mask possible differences between treatments, which could also explain the lack of disparities observed in the flight speed measurements.

No significant differences were observed in the flight speed measurements. Likewise, there was no effect on body weight, except for a observation period effect. After selecting the groups by randomisation, the average weight of the control group (CO) was lower already at the baseline recordings.

However, the results showed that heifers which did not receive any kind of pain relief may have been tenser when they returned to the containment crush 5 days after the procedure. These results indicate a short-term negative effect of hot-iron branding without any type of pain relief on the animals. However, at 60 days after branding, no medium-term time effect on behaviour was observed, with reactions of fear and stress still present in all the groups.

6.3.2 Use of pain relief

Use of effective methods to control pain caused by hot-iron branding has not been studied thoroughly. One study found that a single injection of a non-steroidal anti-inflammatory drug did not provide measurable pain relief (Tucker *et al*., 2014), which is consistent with the results in Paper IV. Moreover, using injected anaesthetics and analgesics may not be very practical in commercial farming, as it means a significant extra cost for the drug and the extra time required (Petherick, 2005). In addition, such a procedure would extend the period of restraint for the animals and/or require them to be handled twice, which may constitute a welfare issue for animals not accustomed to handling (Mellor & Stafford, 1999). The need for a veterinarian to administer the injections correctly could also pose a problem for remotely located farms with limited access to veterinary services. Injecting drugs into the animals could also interfere with the customised animal health and welfare standards for beef production in some markets (*e.g*. Petherick, 2005).

6.3.3 Risks, cost and benefit

Performing hot-iron branding involves a high risk for the handler. The branding site is situated close to the animal's eye, and hence it is necessary to hold the animal's head firmly between the hands (often bare) to avoid hurting the animal. This adds an increased risk of accidents and injuries, which could involve both the animal and the handler.

The farm on which the work in Paper IV was performed had adequate facilities to manage the animals and provided training for its workers, who were experienced and did not show any negative interaction with the animals. This is not the case on all farms, especially those suffering economic constraints, which make up the majority of farms in Brazil. If conditions on the study farm had been different, other results could have been obtained. Therefore, traumatic (related to mental wellbeing and human-animal interactions) effects on cattle need more investigation, as do iron branding in different parts of the body and different restraining and training conditions.

Under current law in Brazil, it is mandatory to carry out facial iron branding to prove that the brucellosis vaccine has been administered. Use of pain relief during this statutory procedure is not always an option, so less painful alternatives should be introduced, e.g. use of serial ear tags or certificates for the whole herd. An official, more controlled system might also be more useful, as it is possible to brand calves without vaccinating them.

6.4 Methodological considerations

6.4.1 Science under commercial farming conditions

Unlike the wide possibilities on experimental farms, collecting data on commercial farms can represent challenges. These include lack of control over the living conditions of the animals or over the time that can be spent on assessments, and unexpected changes to management routines and other plans. However, it also gives a number of advantages, such as working in an environment which reflects common commercial practices, resulting in

accurate and valuable data representative of the actual situation in farming (Wallgren, 2019).

6.4.2 Paper I

Paper I investigated whether a standardised animal welfare assessment approach designed for intensive, technologically advanced farms, *i.e.* the Welfare Quality® protocols, can be used to assess dual-purpose cattle farms in the tropics, which are essentially pasture-based systems. The main challenge in the study was that the tool used was a standardised protocol originally designed for a completely different production system, *i.e.* intensive indoor animal rearing. Animals and farming culture on intensive farms greatly differ from those on pasture-based, dual-purpose subsistence systems in the tropics. Another standardised method could have been chosen to assess animal welfare under the conditions prevailing in tropics, but none of those available was developed specifically for these conditions and could have involved similar constraints. Another option could have been to assess only the measures that apply in tropical farming conditions and separate the results only at the most basic level, but this would not have provided the opportunity to compare the general state of welfare of these farms.

Another issue is that certain parts of the Welfare Quality® protocols rely on information which may not always be available on smallholder farms in the tropics, due to the culture and/or natural conditions on the farms. The lack of production records on the farms and the limited possibility to assess the whole farm due to the large pastureland area meant that it was sometimes necessary to rely on information provided by the farmer. A decision was made to trust the farmers in the study, as long as the evidence did not contradict their word. Therefore, some information may not represent the complete truth. However, this does not affect the main conclusions of Paper I, which focused on the applicability of the assessment protocol, rather than the actual results for the farms. Nevertheless, for further studies or actual assessments where animal welfare classification is critical, it would be best to base the assessment on factual evidence or, if evidence is lacking, repeat the assessment when the information becomes available.

Applying the Welfare Quality® protocols is time-consuming. A few studies have made suggestions on how to optimise the assessment (*e.g.* de Vries *et*

al., 2013), but none of these has been a thorough analysis and therefore optimisation of the system needs further investigation. The community in Mexico in which the study in Paper I was based is fairly remote and, due to the limited resources available, our presence on the farm was brief, affecting the number of farms we could assess. In addition, the high temperatures in the tropics, particularly during the summertime, resulted in a limited number of working hours. The number of consecutive hours spent each day performing the assessment was also limited due to this factor.

6.4.3 Paper II

Paper II used the Welfare Quality® protocol for dairy cattle to evaluate animal welfare on intensive, semi-intensive and extensive dairy production systems in Central America (Costa Rica). One of the main challenges in the study was similar to that in Paper I, *i.e*. assessing different production systems using the same parameters and with the same demands, possibly resulting in biased results, favouring one system or another in different measures of the protocol.

The size of the sampled groups was rather variable in Paper II. This was because of the limited availability of farms working with a more high-tech system in the tropics and the limited possibility to gain access to perform studies on these farms. Thus, we assessed 31 extensive farms and 24 semi-intensive farms, but only five intensive farms.

6.4.4 Paper III

Paper III compared animal welfare status in the two distinct seasons in the tropics, the wet and the dry season. Performing an experiment comparing animal welfare assessment in two different seasons on the same commercial farms was quite challenging. Finding volunteer farmers to perform the first phase of the study was relatively easy but getting access to the same farms for the second assessment was not possible in some cases, and the final sample size was reduced because of this. It was decided not to include the farms that were assessed only during the first assessment period, because it might have affected the comparison of the two seasons, for which data for the same farms in both seasons were needed.

Due to time and economic constraints, the study was performed in only one rainy and one dry season, and the results might have been influenced by the specific characteristics during that specific year. For more accurate conclusions, the ideal experimental design should involve repeated sampling of a larger number of farms in both seasons in a number of different years.

6.4.5 Paper IV

Paper IV examined the effects of facial hot-iron branding in heifers and whether any positive effects of pharmaceutical interventions for pain control might be beneficial to animal welfare. Since facial hot-iron branding is compulsory in Brazil, the possibility of having a control group with no facial branding was not an option. Hence the best-case scenario for this experiment was unattainable. In addition, as this practice is not performed outside Brazilian commercial farms, no anaesthetic protocols to correctly block the area where the branding takes place are available. The experimental treatments tested in Paper IV sought to block the nerves in and around the affected area, but it was not possible to confirm that this treatment eliminated the pain completely.

The extra management and additional time in the management pen and chute required to perform pain relief affected not only the animals, increasing stress, but also the staff on the farm. After the first batch of animals, the workers were less keen to cooperate with the study, as it interfered in their normal routine. Due to this, parts of the original design had to be modified in order to complete the study. Ideally the baseline behaviour of the heifers should have been assessed one day before the branding procedure but moving the animals to the management area only for a preliminary assessment was not feasible. Hence, the baseline recordings took place on the same day as the branding, resulting in extra management time in one day and more stress for the animals. However, all groups were assessed under the same circumstances, so this modification affected all the individuals similarly, and the general conclusions should not have been influenced by this shortcoming.

7. Main Conclusions

Assessment of animal welfare in cattle raised in pasture-based systems can differ from that on intensive European farms for which the current standardised protocols were designed, such as the Welfare Quality® protocols.

Overall, the Welfare Quality® protocols proved useful in assessing animal welfare on tropical dual-purpose cattle farms in Papers I and III of this thesis. However, some aspects assessed by the protocols, such as 'absence of prolonged thirst', 'animals injured by housing equipment' and 'social interaction', are more appropriate for the conventional intensive farming systems predominantly used in Europe. Thus, some modifications to the protocols were needed during assessments on tropical farms. In Paper II, the original protocol was followed, in order to obtain a more reliable comparison between the farming systems and because the farms studied were more specialised, thus better resembling the farms for which the Welfare Quality® protocols were designed.

Paper III showed that overall animal welfare can be more at risk during the rainy season. However, it also showed that if certain management modifications, such as providing extra water points and supplementary feeding, are not performed during the dry season, animal welfare conditions might also be jeopardised during this period.

Further studies under slightly different management situations should be performed to investigate whether the discomfort reactions observed in Paper IV are related to pain, fear or the restraint itself. The overall conclusion is that hot-iron facial branding represents an obvious welfare issue, not only because of the painful procedure itself, but also the restraint needed and the fearful situation, where the animals showed an obvious negative reaction.

Paper IV indicated that these problems cannot easily be solved by applying a simple pain control protocol. Hence, facial branding should be completely phased out, rather than handled in terms of pain relief, as the practice is not animal welfare-friendly and is also not a necessary or efficient way of ensuring proper vaccination status.

In general, the results obtained in this thesis demonstrate that the animal welfare status of cattle raised under tropical conditions can be very variable. Broadly, the Welfare Quality® principles of good housing and appropriate behaviour can be considered strengths in the region. However, the principles of good feeding and good health were major weaknesses for the majority of farms assessed in this thesis. The good health principle is particularly compromised by the performance of statutory painful procedures on animals without the use of pain relief. These weaknesses represent an obvious risk to animal welfare and must be overcome to improve the attractiveness to modern consumer of animal products from developing countries in the tropics.

8. Future Research

Further research on what constitutes an actual welfare risk for animals raised in a pasture-based system is needed, in order to develop a protocol that can assess the true animal welfare status of such farms, regardless of the geographical area in which they are located.

Paper III was carried out in only one dry and one wet season, and therefore between-year variations in seasonal climate in the region were not covered. Hence, more research on seasonal effects is needed.

Assessment of pain, particularly animal pain, is still quite subjective and the possibilities to correctly interpret what the animal feels are still limited. Further studies are needed in order to identify the true expressions of short- and long-term pain in production animals and its consequences for production, animal behaviour and the human-animal relationship.

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Popular science summary

Farm animal welfare has become an important issue for modern societies. People in emerging economies are rapidly achieving higher purchasing power and are also becoming more aware about their consumption habits and the production conditions of the products available on the market. However, some enterprises are being left behind by this development, either because they are not able to compete against larger and more well-established production systems or are not capable of providing adequate proof of animal welfare and sustainable conditions that consumers demand nowadays. This is primarily affecting small producers in developing countries, such as those in tropical areas of the world. There, it is adding to social problems already affecting the region, such as increasing migration of people to cities, increasing poverty and inequality, and abandonment of traditional, possibly more sustainable, forms of animal production.

Standardised animal welfare assessment protocols are becoming a useful tool helping researchers, farmers and consumers gain a better understanding of the actual state of animal welfare. They are also being used to create standards and trademarks in commercialisation of products. However, existing assessment protocols designed and standardised to map the characteristics of intensive, large-scale Western farming may not be suitable for small-scale farms in tropical countries. Therefore, modified protocols may be needed to change old harmful practices and improve trade in products essential for the survival of enterprises that provide the only livelihood for many rural people in developing countries.

This thesis investigated the general animal welfare status of cattle raised under tropical conditions and looked at areas in need of improvement. Studies were carried out on extensive beef and dairy farms in Mexico and on

intensive (enclosure), semi-intensive (part-enclosure, part-pasture) and extensive (pasture) dairy farms in Costa Rica, to examine whether the Welfare Quality® protocols, which are created and designed for intensive farming in the European Union, can be applied directly to assess farms in the tropics mostly using pasture-based systems. A further study in the Mexican tropics investigated whether the indicators relating to animal welfare evaluated by the Welfare Quality® protocols are affected by the dry or rainy season, requiring specification of assessment season from a risk-based perspective. In these studies, it was observed that performing painful procedures without any source of pain relief was one of the major threats to animal welfare, so this issue was investigated in a separate study. That study examined the effects of facial hot-iron branding in heifers, a statutory post-vaccination procedure on heifers in Brazil, and positive effects of pharmaceutical interventions for pain control on animal welfare and on the human-animal interaction. Three different pain relief approaches were compared with a control treatment without the use of pain relief.

The results showed that the Welfare Quality® protocols can be useful for evaluating the animal welfare status of cattle raised under tropical conditions. However, they also demonstrated a need to modify certain aspects of the original Welfare Quality® protocols for dairy and beef cattle, in order to accurately evaluate animal welfare under the conditions prevailing in small community farming in the Mexican tropics. It was found that, overall, animal welfare on tropical farms can be more at risk during the rainy season. However, it was also found that if certain management modifications, such as providing extra water points and supplementary feeding, are not performed during the dry season, animal welfare conditions might be jeopardised also during this period.

Based on assessments of facial and body signs of pain in heifers, the different pain relief approaches tested did not give significant differences for the majority of pain indicators. However, some variables indicated inadequate animal welfare in the control group. Performing painful procedures without the use of pain relief represents an obvious welfare issue because of the painful procedure itself, but also because of the whole restraining procedure and the fearful situation, where the animals showed an obvious negative reaction. The results indicated that these problems cannot easily be solved by applying a simple pain control intervention.

In general, the results obtained in this thesis show that the animal welfare status of cattle raised under tropical conditions can be very variable. The principles of good housing and appropriate behaviour can be considered animal welfare strengths of farms in the region. Animal welfare weakness relate to body condition, access to good quality water and performance of painful procedures without pain relief. These weaknesses represent an obvious risk to animal welfare and must be overcome to improve the attractiveness to modern consumer of animal products from developing countries in the tropics.

Populärvetenskaplig sammanfattning

Djurskydd för lantbrukets djur är en viktig fråga för människor i det moderna samhället. Även människor i tillväxtländer får ökad köpkraft och blir samtidigt medvetna om sina konsumtionsvaror och produktionsförutsättningarna för de produkter som finns på marknaden. Parallellt med denna utveckling finns det företag som hamnar på efterkälken, antingen för att de inte klarar att konkurrera med större och mer etablerad produktion eller för att det till exempel inte kan visa att de på ett adekvat sätt lever upp till de djurskydds- och hållbarhetsförutsättningar som nutidens konsumenter kräver. Denna situation påverkar främst mindre producenter i utvecklingsländer såsom de som finns världens tropiska regioner. Detta får effekter utöver flera andra sociala problem som redan påverkar dessa regioner, såsom urbanisering, ökande fattigdom och växande samhällsklyftor, medan traditionella och möjligen mer hållbara former av djurhållning överges.

Standardiserade djurvälfärdsbedömningsprogram har blivit ett användbart verktyg. De hjälper forskare, lantbrukare och konsumenter att bättre förstå det faktiska läget vad gäller djurvälfärd och kan också användas för att skapa märkningssystem och varumärken som ger ökade möjligheter till förtjänst vid försäljning av produkterna. Därför behövs bedömningsprotokoll som är standardiserade och anpassade till de ovan nämnda mindre besättningarna i tropiska länder. Att förändra äldre, skadliga sätt att hantera djuren har blivit avgörande för att sådana småföretag ska kunna överleva, företag som ofta utgör den enda inkomstkällan för en stor andel av befolkningen i dessa områden.

Det övergripande målet med denna avhandling var att undersöka djurvälfärdssituationen för nötkreatur i tropiska regioner och identifiera områden där den här typen av småföretag behöver förbättra sin djurhållning.

Denna avhandling baseras på fyra studier (studie I, II, III och IV). The första tre studierna fokuserade på hur bedömningsprotokollen inom djurvälfärdsprojektet Welfare Quality® (WQ®), som är skapat och utformat för intensiva djurhållningssystem av europeisk typ, kan användas och anpassas för att bedöma nötkreatursbesättningar i tropikerna, och då främst betesbaserad djurhållning. Den fjärde studien fokuserade på en av de allvarligaste faktorerna kopplad till nedsatt djurvälfärd som noterats på dessa gårdar i tropikerna, nämligen utförandet av smärtsamma ingrepp utan någon typ av smärtlindring.

Studie 1 syftade till att illustrera vikten av att modifiera vissa aspekter av de ursprungliga WQ®-protokollen för mjölk- och köttdjur för att på ett korrekt sätt kunna utvärdera djurvälfärden för mjölk- och köttdjur under de förhållanden som dominerar inom småbruket i de mexikanska tropikerna. I studie II användes WQ®-protokollen för mjölkkor för att utvärdera djurvälfärden i mjölkkobesättningar i Costa Rica, i system för intensivt hållna (fållor), semi-intensivt (delvis i fållor, delvis på bete) och extensivt hållna (enbart på bete) djur. Studie III syftade till att undersöka om det finns djurvälfärdsindikatorer i WQ®-protokollen som påverkas av årstid (torr- respektive regnperiod), för att underlätta valet av tidpunkt för djurvälfärdsbedömningarna, ur ett riskbaserat perspektiv. Studie IV syftade till att undersöka effekterna av brännmärkning i ansiktet på kvigkalvar, såsom om det gick att se några positiva effekter av olika typer av smärtstillande preparat på djurvälfärden, och om det fanns några effekter av denna hantering på förhållandet mellan djuren och människor. I samband med sedvanligt hanterad brännmärkning av kvigkalvar i Brasilien, där djuren vanligen brännmärks helt utan smärtlindring, jämfördes tre olika metoder för smärtlindring med en kontrollgrupp som inte fick någon sådan behandling.

Studie I och II visade att de standardiserade bedömningsprotokoll som utvecklats för konventionella nötkreatursbesättningar i västvärlden, såsom WQ®-protokollen, var användbara även för att utvärdera djurvälfärden hos nötkreatur i tropikerna. Dock skilde sig vissa av förutsättningarna åt, och det finns därför ett behov av att genomföra ett antal modifieringar i protokollen

om djurvälfärden i besättningar i tropiska regioner ska bedömas på ett korrekt och effektivt sätt.

Av studie III kan utläsas att välfärdriskerna generellt är större under regnperioden. Om nödvändiga justeringar i skötseln av djuren, såsom att tillgängliggöra dricksvatten på fler platser och ge djuren tillskottsfoder, inte görs finns det dock risker för brister i djurvälfärden även under den torra delen av året.

Studie IV visade att man vid bedömning av tecken på smärta i djurens kroppshållning eller ansiktsuttryck inte kunde se någon skillnad mellan de fyra försöksgrupperna för de flesta av indikatorerna. Det fanns dock vissa variabler som tydde på brister i djurvälfärden i kontrollgruppen. Att utföra smärtsamma ingrepp utan bedövning innebär ett uppenbart djurskyddsproblem. Detta inte bara på grund av smärtan i sig, utan också på grund av hela processen med fixering inför ingreppet och en situation som innebär rädsla, där djuren visade tydliga tecken på negativa reaktioner. Studien indikerar att dessa problem inte enkelt kan lösas genom att smärtlindring används.

Resultaten från de studier som ingår i denna avhandling innebär att vi kan dra slutsatsen att djurvälfärden för nötkreatur i tropikerna varierar kraftigt. Rent allmänt kan inhysning och beteende hos djuren ses som styrkor in de aktuella regionerna. Däremot ses svagheter i nuvarande system vad gäller möjligheten att hålla djuren i gott hull, ge dem tillgång till dricksvatten av god kvalitet, samt vad gäller förekomsten av smärtsamma ingrepp utan smärtlindring.

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Improvements in Animal welfare and changes to old harmful practices have become essential for the survival of small cattle farms in the tropics. This thesis investigated animal welfare in cattle raised under tropical conditions. The results obtained demonstrate that animal welfare in the region can be very variable. Housing and behaviour were the major strengths. However, body condition, access to quality water and performance of painful procedures without using pain relief were the major weaknesses for the majority of farms assessed.

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