Automatic Welfare Assessment in Broilers

with focus on Human-Animal Relationship and Lameness

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Doctoral Thesis
Swedish University of Agricultural Sciences
Uppsala 2017

Acta Universitatis Agriculturae Sueciae
2017:42

Cover: Ross 308 broilers during my first experiment at the Swedish Livestock Research Centre in Uppsala, Sweden
(photo: Johan Silvera)

ISSN 1652-6880
ISBN (print version) 978-91-576-8857-6
ISBN (electronic version) 978-91-576-8858-3

Print: SLU Service/Repro, Uppsala 2017

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Abstract

Broiler production today is an intensive farming sector with large flocks which can make it difficult for farmers to continuously monitor the animals. At the same time, society demands good animal welfare and the possibility to buy animal welfare certified products. Difficulties with the application of existing animal welfare assessment protocols are the time and effort needed for a complete assessment on farm and consequently long intervals between assessments. This hampers the use of the outcomes as a management tool. Automatic and (semi) continuous monitoring of welfare, production and other management parameters could solve that problem. In this thesis the possibilities to automatically assess two welfare parameters in broilers, human-animal relationship and lameness, were investigated in detail. The automatization was based on image analysis techniques.

Study I was designed to investigate the possibility to affect the human-animal relationship through additional human contact and the effect on the birds' productivity. The additional human contact treatment had a positive effect on the quality of the human-animal relationship but failed to affect any production parameter. The possibilities to use automatic recordings of broiler chicken activity to assess the human-animal relationship and the birds´ walking ability were investigated in Study II and III respectively. The results show that changes in broiler activity, in response to the presence of a human, can predict the human-animal relationship (Study II) and the level of lameness (Study III). Study IV focused on leg health in broilers from an economic perspective. The first aim was to explore the economic potential of management practices intended to reduce broiler lameness. Secondly it was investigated through a survey how Swedish broiler farmers perceive these management practices.

The results in this thesis show the potential of using automatic image analysis techniques to assess the quality of the human-animal relationship and lameness in commercial broiler flocks and thus can be of use in animal welfare assessment. Results also show that it is possible to positively modify the human-animal relationship and that there is an economical potential to use alternative practises to reduce lameness.

Key words: precision livestock farming, image analysis, welfare, lameness, human-animal relationship, economy

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Everything is theoretically impossible, until it's done.

Robert A. Heinlein

Contents

List of Publications

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

I Silvera, A.M., Wallenbeck, A., Butterworth, A. & Blokhuis, H.J. (2017). Modification of the human-broiler relationship and its potential effects on production. *Acta Agriculturae Scandinavica, Section A — Animal Science* Published online. DOI: 10.1080/09064702.2017.1286379

II Silvera, A.M., Knowles, T.G., Butterworth, A., Berckmans, D., Vranken, E. & Blokhuis, H.J. (2017). Assessment of the human-animal relationship in commercial broiler flocks using automatic monitoring of activity. *(Manuscript)*

III Silvera, A.M., Knowles, T.G., Butterworth, A., Berckmans, D., Vranken, E. & Blokhuis, H.J. (2017). Lameness Assessment With Automatic Monitoring of Activity in Commercial Broiler Flocks. *Accepted by Poultry Science.*

IV Gocsik, E., Silvera, A.M., Hansson, H., Saatkamp, H.W. & Blokhuis, H.J. (2017). Exploring the economic potential of reducing broiler lameness *British Poultry Science*. Published online. DOI:10.1080/00071668.2017.1304530

The contribution of Anna Silvera to the papers included in this thesis was as follows:

I Was involved in planning and execution of the work. Responsible for summarising the results. Main responsibility for completing the manuscript with regular input from co-authors.

II Was involved in planning and was coordinator for the data collection. Involved in analysis and responsibility for summarising the results. Main responsibility for completing the manuscript with regular input from co-authors

III Was involved in planning and was coordinator for the data collection. Involved in analysis and responsibility for summarising the results. Main responsibility for completing the manuscript with regular input from co-authors.

IV Was involved in planning of the study and responsible for execution and interpretation of the questionnaire. Involved in manuscript writing together with main author and other co-authors.

Abbreviations

AHC	Additional Human Contact
BCN	Bacterial Chondronecrosis
FCR	Feed Conversion Ratio
FTE	Full Time Labour Equivalent
GLM	General Linear Model
GS	Gait Score
HD	High Density
LD	Low Density
PLF	Precision Livestock Farming
RT	Rotated Tibia
TD	Tibial Dyschondroplasia
SD	Standard Deviation
SL	Spondylolisthesis
TT	Touch Test
VVD	Valgus/Varus Deformity
WQ	Welfare Quality®

1 Background

Due to increasing meat consumption and a growing population, animal production is increasing in the world (Food and Agriculture Organization of the United Nations FAO, 2016). This increase is realised through fewer, but larger farms (large animal units and high stocking densities and with large numbers of animals per farm) in upper middle-income countries and high-income countries (Lowder et al., 2016). This increase in farm size could result in fewer opportunities for one farmer to monitor health and welfare status of the animals, since, at least in developed agricultural economies, labour is expensive and the profit margin in livestock production is limited (Wathes et al., 2008). This contradicts the increasing demand from consumers for good animal welfare, food quality and safety (Appleby et al., 2003).

With regard to number of animals, poultry production (with broilers being the most commonly reared poultry species) is one of the largest livestock sectors in the world. Globally 21.3 billion broilers were produced in 2014 (Food and Agriculture Organization of the United Nations FAO), with China, USA, Indonesia and Brazil being the top four producing countries. Figure 1 show how the broiler production is divided over the different continents.

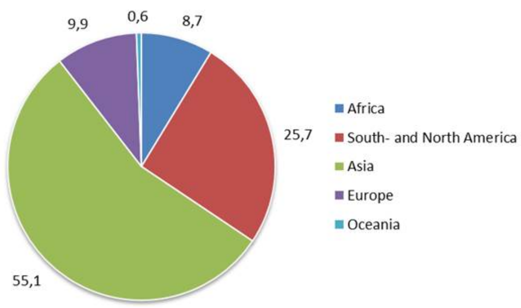

Figure 1. Percentage (%) broiler chickens produced in different parts of the world (FAO, 2014).

One reason for the enormous amount of broiler chickens that are reared for meat production is the growing market for chicken products. Chicken has gone from a dish served at special occasions, to a cheap everyday food item (Lymbery, 2004). Their fast growth and short life span increases the yearly capacity for production on farm and thus can meet the market demand. Through intensive genetic selection broiler chickens are among the most fast-growing livestock species (Weeks, 2004). Starting as newly hatched with a weight of about 40 gram the broiler chicken is ready for slaughter about 35 days later, weighing approximately 2000 grams with a feed conversion ratio around 1.5-1.6 (Aviagen group, 2016, Cobb Vantress Inc., 2016). The fast growth rate and the intensive farming are the two main reasons for impaired broiler welfare (Weeks, 2004). As pointed out by Weeks (2004) the broiler production is the most uniform way of all animal production types, considering the genotypes used, feeding strategies, housing and handling. This uniformity promotes the possibility to assess and improve broiler welfare, with animal welfare standards and assessment schemes. Results can be compared on a global scale, since the production is similar to each other regardless of origin.

To improve animal welfare in livestock production and develop a benchmarking assurance scheme, the Welfare Quality® project started in 2004 with the intention to develop science-based, on-farm welfare assessment systems for poultry, pigs and cattle (Blokhuis et al., 2010, www.welfarequalitynetwork.net). The Welfare Quality® project was the largest European research project on animal welfare ever and was funded by the European sixth Framework Programme for Research and Technological Development. The project defined four basic principles for good animal welfare which were further specified in 12 welfare criteria (see Table 1, Blokhuis et al., 2010). Welfare Quality® then set out to develop reliable and feasible measures for these welfare criteria to assess the level of welfare on farm and at slaughter. The emphasis was placed on animal-based measures (also called 'outcome' or 'performance' measures) in an attempt to estimate the actual welfare state of the animals on the basis of, for instance, their behaviour, fearfulness, health or physical condition. One specific difficulty in the application of the existing Welfare Quality® assessment protocols is the time and effort needed for a complete assessment on farm. An assessor has to be trained to perform the assessments; this person has then to travel between farms, which due to labour costs can be expensive. The assessment also becomes a snap shot of the welfare state of the flock at that specific moment in time, which could mean that it could be too late to take measures to mitigate any welfare problems. A person visiting several farms may also risk spreading diseases between flocks, risking the on-farm biosecurity.

A possible way of reducing the workload and the other implications mentioned, is to automate the assessments using the technologies available in the area of Precision livestock farming (PLF). Wathes et al. (2008) defines PLF as the management of livestock production using the principles and technology of process engineering. The main advantage of PLF is the possibility of automatic, real-time and simultaneous monitoring of various parameters in the production (Wathes et al., 2008). Usage of data that are collected during the whole rearing period would also give the farmer the potential to use the information as a management tool in his or her daily work.

In this thesis the possibility to assess two parameters for broiler welfare, using the principles of PLF, will be investigated in detail; Human-Animal Relationship and Lameness. The possibility of modifying human-animal relationship in broiler flocks and the economic effects of using alternative practices to reduce lameness were also explored.

Table 1. *The welfare principles, criteria and measures specific for broiler chickens in the Welfare Quality®-protocol.*

Principles	Welfare criteria	Measures
Good feeding	Absence of prolonged hunger	*This criterion is measured at the slaughterhouse*
	Absence of prolonged thirst	Drinker space
Good housing	Comfort around resting	Plumage cleanliness, litter quality, dust sheet test
	Thermal comfort	Panting, huddling
	Ease of movement	Stocking density
Good health	Absence of injuries	Lameness, hock burn, foot pas dermatitis
	Absence of disease	On farm mortality, culls on farm
	Absence of pain induced by management procedures	This criterion is not applied in this situation
Appropriate behaviour	Expression of social behaviours	As yet, no measure is developed
	Expression of other behaviours	Cover on the range, free range
	Good human-animal relationship	Avoidance distance test (ADT)
	Positive emotional state	Qualitative behaviour assessment (QBA)

2 Introduction

2.1 Human-Animal Relationship

In livestock production, the stockperson interacts with individual animals to different degrees depending on animal species and production type. Common for all systems is the fact that a relationship is formed between the human and the animals (Hemsworth and Coleman, 2011). In poultry production, the physical contact between the stockperson and the birds is usually limited. Notwithstanding the lack of physical contact, the farmer's behaviour and the frequency of contact still affects the birds, and a 'relationship' is formed, (Cransberg et al., 2000; Silvera et al., 2017a).

2.1.1 The concept of human-animal relationship

A relationship between animals can be described as the interaction between two or more individuals, which is a type of interindividual communication (Hinde 1976). Hinde (1976) proposes a conceptual framework in three levels to describe how relationships and social structures are formed (Figure 2). In this thesis, the focus will be on the first two levels; interactions and relationships. The first level describes interactions, which is a necessary element for relationships to be formed. Interactions can, as mentioned above, involve two or more individuals and one or several types of behaviours. If the interactions extend in time, the interacting individuals will become familiar to each other and level two in the framework is reached; a relationship. The familiarity of the interacting individuals is not the only criterion for defining relationships. Previous experiences, expectations, the quality and content of the interactions are also important factors to determine the quality of the relationship.

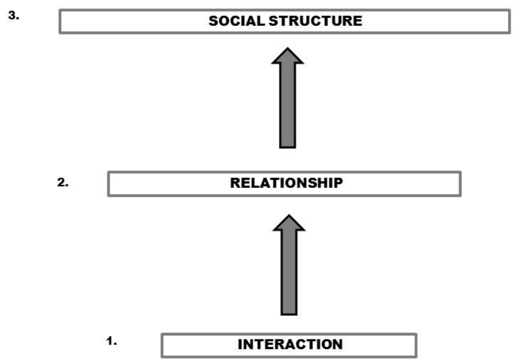

Figure 2. A three level framework describing the formation of relationships and social structure (Hinde, 1976)

The human-animal interaction, which is the first step to create a relationship according to Hinde´s (1976) framework, can be divided into different types of contact: visual, tactile, olfactory and auditory (Waiblinger et al., 2006). A stockperson can for example be just visible to the animals or also touch the animals by moving around in the herd or flock. Stationary or in motion, the stockperson may also communicate with the flock using the voice with or without tactile stimuli. In several livestock production systems, the stockperson does handle the animals daily, resulting in several multi-faceted contacts every day. The contacts (visual, tactile, olfactory or auditory) can be perceived by the animal as negative, positive or neutral and this affects the quality of the relationship between human and animals. This can be summarized on an emotion-based level in two dimensions: positive/pleasant and negative/unpleasant (Figure 3). Pleasant emotions are generated by rewarding events, such as feeding or grooming. Unpleasant on the other side can be punishing events, social isolation or various types of rough contact with the animals.

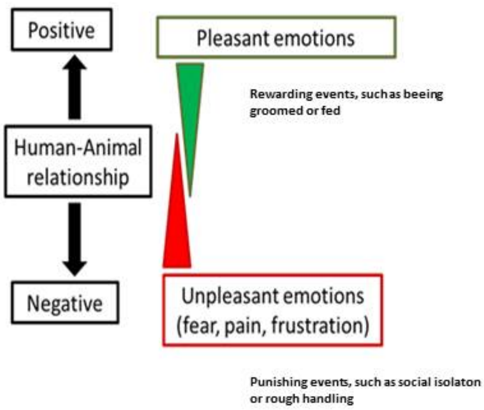

Figure 3. The effect of pleasant and unpleasant emotions on the human-animal relationship (Waiblinger et al., 2006).

When the interaction between human and animal has become frequent enough for the animals to be familiar with humans, the next level in Hinde´s (1976) framework, a relationship, is reached. Hediger (1965) presents five definitions of how animals can perceive the relationship with humans. The definitions are divided into the following categories; human as a predator, human as a prey, human as a symbiont, human as part of the environment without social importance and human as a member of the animals' own species. Estep and Hetts (1992) imply that the framework that Hinde (1976) presents may be interactive between levels and not just hierarchical. For example, if an animal has previous experience from a relationship, that may affect present or future reactions to humans. This suggests that the human-animal relationship is a concept that is based on the framework above, but is also dependent on former experiences.

Another aspect affecting the human-animal relationship is the attitude of the human. The stockperson's attitude towards animals and animal handling can play an important role in how he/she behaves when in contact with the animals (Hemsworth et al., 1989). A positive attitude indicates a high probability that the stockperson will handle the animals in a less aversive way. A study of attitudes of poultry farmers towards their birds was presented by Bock et al. (2007). Regardless of the production type or housing system (eggs or meat, conventional, free range or organic), the farmers perceived their animals as a 'flock' or 'production units' rather than individuals. Despite this de-attachment attitude to their animals, poultry farmers were still concerned about the birds' wellbeing and quality of life, which may have a positive effect on their behaviour towards their birds.

A good human-animal relationship does have a positive effect on production results. In for example pigs, dairy cows and calves, a high-quality human-animal relationship showed positive effects, such as higher growth rate, lower cortisol levels, a positive impact on pregnancy rates and milk production (Hemsworth and Barnett, 1991; Hemsworth et al., 1986; Gonyou et al., 1986; Rushen et al., 1999; Breuer et al., 2000; Waiblinger et al., 2002). In poultry the effect of a good human-animal relationship on production has been seen in lower first week mortality (Cransberg et al., 2000), improved feed conversion ratio (Gross and Siegel, 1979) and growth rate (Zulkifiki and Siti Nor Azah, 2004) in broilers and higher egg production (Barnett et al., 1994) in laying hens.

2.1.2 Fear and Human-Animal Relationship

Fear may be defined as "a psychophysiological response to perceived danger, with fear behaviour ideally functioning to protect the animal from injury" (Jones, 1987). Hemsworth et al. (1993) propose that elevated fear levels impair animal welfare, since fear is considered to be an emotional state of suffering (Jones and Waddington, 1992). Also other authors state that a high and/or prolonged level of fear is likely to have a negative impact on animal welfare (Hemsworth et al., 1993; Duncan, 1992; Jones, 2001). If the human-animal relationship has a low quality it is conceivable that the birds perceive the stockpersons as frightening predators (Jones, 1987; Duncan, 1992).

General fear' and 'fear of humans' are thought to be two distinct states in the case of poultry. Several methods have been used to investigate fearfulness in poultry, including novel object, open field, human approach, social dispersal, tonic immobility etc. (Jones, 1996; Jones and Boissy, 2011). Chicks exposed to environmental enrichment showed reduced fearfulness in a variety of tests whereas those receiving regular handling or visual contact with people were less fearful only in tests incorporating a strong human component, which indicates that the effect was stimulus specific (Jones; 1994; Jones, 1995; Jones and Waddington, 1992). Similar findings were reported by Barnett et al. (1994) and Graml et al. (2008) and may be relevant to the choice of assessment methods.

In conclusion, the human-animal relationship is an important component to include in existing welfare assessment protocols, not only due to the effects on welfare, but also due to the effects that the human-animal relationship has on productivity (Blokhuis et al., 2010).

2.2 Lameness

One consequence of the genetic selection for rapid growth rate and high meat yield is an increased risk of lameness and impaired walking ability of individuals in the flock (Knowles et al., 2008; Bradshaw et al., 2002). Their welfare is compromised because lame birds can experience pain (McGeown et al., 1999; Danbury et al., 2000; Caplen et al., 2013) and may have problems accessing feed and water (Bessei, 2006). In a study by Bassler et al. (2013) lameness in conventional broiler flocks in France, the U.K, the Netherlands and Italy was investigated during a period of three years. The average prevalence of birds with impaired gait (gait score ≥ 3 on a scale between 0 representing perfect walk and 5, not able to walk at all) was 15.6%. In another study conducted by De Jong et al. (2011) where welfare in flocks with fast growing hybrids and flocks with more slow growing strains were compared, the prevalence of lame birds (gait score ≥ 3) was 57% in average for the fast growing and 17 % for slow growing. A more recent study in five conventional broiler houses in the U.K, the Netherlands, Italy and Spain (Silvera et al., 2017b) showed a dramatically lower prevalence of lame birds, with a mean gait score of 1.9 at five weeks of age. These findings suggests that the effort put into reducing lameness in broiler chickens by the breeding companies, may have had a positive effect (Kapell et al., 2012) but also indicates that there exists potential for significant inter –farm and inter-company variation in lameness levels.

The factors causing lameness in broilers can be metabolic, developmental or infectious (Butterworth and Haslam, 2009). The metabolic conditions causing lameness that can be seen in intensive broiler production are rickets and chondrodystrophy. Both are related to nutritional imbalance and deficiency and are today rarely seen in broilers, except in cases of feed formulation errors. Developmental disorders are seen as skeletal abnormalities in the animals. Ridell (1992) classified the disorders as follows; valgus/varus deformity (VVD), rotated tibia (RT), spondylolisthesis (SL) and tibial dyschondroplasia (TD). A combination of rapid growth, high body weight and nutritional imbalance is believed to cause these disorders. Bacterial infections are considered to be a common source for leg disorders in broilers in the end of the rearing period (Butterworth and Haslam, 2009), causing bacterial chondronecrosis (BCN) and osteomyelitis. The bacteria infecting the birds are primarily *Staphylococcus aureus*, *Salmonella* and *Escherichia coli*. These infectious disorders can be minimized by good biosecurity in the chicken house and quick removal of dead or diseased birds from the flock. The factors mentioned above may be of different origins and some of them can be prevented by appropriate management practises, such as lighting programs, stocking density, diet and feeding regime or by incorporating improved walking ability into breeding goals (Knowles et al. 2008; Butterworth and Haslam, 2009; Bassler et al. 2013).

2.2.1 Economic impact

Lameness does not only affect animal welfare, but also has an effect on productivity, which most likely will have a negative impact on economy (Bradshaw et al., 2002; Gocsik et al., 2014). Impaired leg health is associated with higher mortality (Verma, 2007; Wideman et al., 2012) and the level of lameness and the final weight at delivery, on a flock level, are negatively related (Butterworth and Haslam, 2009). Results from this thesis by Gocsik et al. (2017) suggest that the application of alternative practices to reduce lameness can provide better economic performance. The practices that showed the greatest improvements in gross margin and net return to management were: feeding whole wheat, sequential feeding and meal feeding.

2.2.2 Lameness assessment

A post-mortem examination of the bird is needed to determine the exact pathological cause of lameness (Mench, 2004) but several methods have been developed to assess lameness in live animals. Two non-invasive methods are the latency to lie (Weeks et al., 2002) and the gait scoring-method (Welfare Quality®, 2009; Kestin et al., 1992). The latency to lie-methods measures the bird's latency (delay) before it lies down, when challenged with standing in a water bath. The birds are placed in a water-proof test pen with the floor covered with tepid water to a depth of 30 mm; severe lameness results in short latencies, whereas birds with good leg health will remain standing for longer. This is an objective measurement of lameness but has time and resource constraints that limit the number of birds that can be tested. The gait score-method is probably the most widely adopted method to assess lameness. The bird's walking ability is graded between 0 (perfect walking) to 5 (not able to move). This observational method enables a large number of birds to be assessed during the same inspection, but it has been criticized for being subjective, having poor reliability between observers (Mench, 2004).

2.3 Automatic animal welfare assessment

Monitoring livestock production has been performed according to the principles of PLF in various animal species. Moura et al. (2008) presented a real time monitoring method to analyze stress levels in piglets. Vocalization of the piglets was recorded by microphones in the stable which were connected to a computer. Subsequently, the noise intensity was related to different stress levels and this formed the basis for a software model to automatically indicate the level of stress. Measuring sound has also been used as a method to relate pig coughs to different pathological conditions of the respiratory system (Silva et al., 2009). Other examples of technology used in livestock production are digital image analysis to estimate the live weight of broilers (Mollah et al., 2010), automatic vision based detection of lameness in dairy cows (Song et al., 2008) and lameness detection in broilers through analysis of optical flow patterns (Dawkins, et al., 2009).

The use of an automatic method to assess aspects of welfare (semi) continuously could help overcome some of the above mentioned problems regarding animal welfare assessment with traditional protocols (Blokhuis et al., 2010). The commercially available eYeNamic™ system (Fancom BV, The Netherlands) uses image processing methods (Kashiha et al., 2013) to automatically monitor the activity and distribution of a broiler flock. In this thesis, the eYeNamic™-system was used to determine if changes in broiler activity in response to the presence of a human being could predict the human-animal relationship and lameness in commercial broiler flocks.

3 Aims of the thesis

The general aim of this thesis was to investigate the possibility of using available technologies to automatically assess aspects of broiler welfare. Two welfare relevant aspects were examined in detail; Human-Animal Relationship and Lameness and the findings are presented in four studies in this thesis. Another aim was to investigate the possibly to modify the human-animal relationship and its effect on productivity. The potential economic effects on reducing lameness was also explored.

Specific aims were to:

- Determine if regular exposure to people reduced fear of humans and whether productivity parameters were affected by a better human-broiler relationship (Paper I).

- Evaluate if changes of broiler activity, in response to the presence of a moving human, as measured with the eYeNamic™-system can predict the human-animal relationship in commercial broiler flocks (Paper II).

- Determine whether changes of broiler activity observed around a moving human were related to Gait Score (Paper III).

- Explore the economic potential of management practices intended to reduce broiler lameness, using a normative economic model and investigate Swedish broiler farmers' perceptions of these management practices (Paper IV).

4 Materials & Methods

This chapter gives an overview of the materials and methods used in the four studies presented in this thesis. For full descriptions and details, see Paper I-IV. Study number one was conducted in March and April 2013 at the Swedish Livestock Research Centre in Uppsala, Sweden. The second and third study were carried out at five commercial broiler farms in Italy, the Netherlands, the United Kingdom and Spain. The data collection lasted from October 2014 to August 2015 (Paper II & Paper III). Study number four includes economic data from Swedish farming, derived from the database Agriwise (2014) and data from a questionnaire that was answered by Swedish broiler famers during August-November 2014 (Paper IV).

4.1 Study I

The aim with study I was to determine if broilers' fear of humans can be reduced by regular exposure to people and whether productivity parameters are affected by a better human-broiler relationship.

4.1.1 Animals and housing

The study took place at the Swedish Livestock Research Centre in Uppsala, Sweden and was ethically approved by the Swedish Ethical Committee on animal research (permit number: C 308/11). A total of 1558 broiler chickens (Ross 308, Aviagen group Ltd) were placed in 12 pens, each measuring $12m^2$, and reared on the floor with wood shavings as litter, until 33 days of age. The birds were placed in the pens as follows: 4 pens with 194-195 birds (32 kg/m2, high density (HD)) and 8 pens with 97-98 birds (16 kg/m2, low density (LD)) to evaluate if stocking density had any effect on the parameters measured. They were given a standard broiler diet and both feed and water were provided ad lib.

4.1.2 Measures

To investigate if fear of humans could be reduced by regular human contact, six groups (2 HD and 4 LD) received Additional Human Contact (AHC) during the experiment. This consisted of a 30 minutes session on each of 3 days/week (Figure 4). A session began when a person entered the pen and sat still at location A for 5 minutes, then slowly walked to location B and sat down for 5 minutes and finally sat down at location C for 5 minutes. The person then left the pen, entered it again at location A and repeated the procedure one more time.

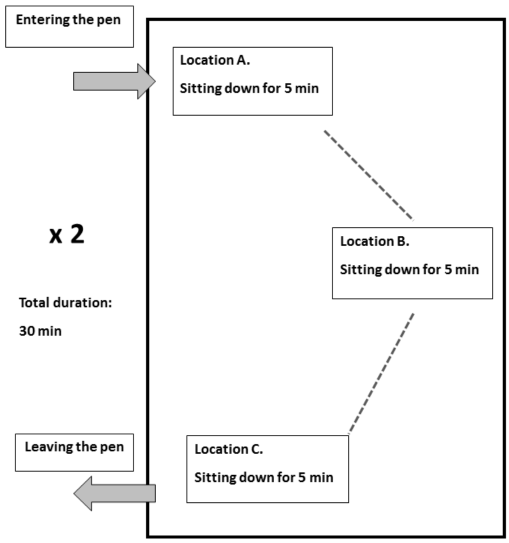

Figure 4. The Additional Human Contact-procedure (AHC).

The remaining six groups were regarded as controls and received as little human contact as possible. All birds (both treatment- and control groups) were checked twice a day for feed, water and presence of sick birds. The control and AHC groups were kept in the same large house but there was no visual contact between the two treatment groups (Figure 5).

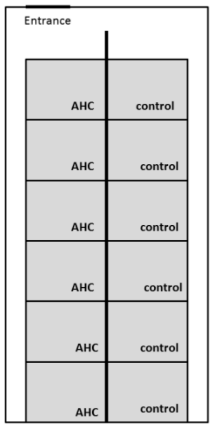

Figure 5. Schematic picture of the stable and the experimental design. AHC-groups and control-groups were separated with no possibility for visual contact

The birds' responses to humans were assessed once a week using the Touch Test (TT) described by Graml et al. (2008). The assessor approached a group of at least three birds, squatted, counted the number of birds within arm's length and the number that could actually be touched. This was repeated 5 times per pen. The proportions of animals within an arm's length that could be touched were calculated. The results are presented as percentage birds that could be touched.

To follow the birds' performance, approximately 50 birds/pen were randomly selected, caught and weighed by hand every week. The number of dead and culled birds was recorded every day and the reasons for culling, e.g. leg problems or sickness, were carefully noted. The feed was weighed when provided on a daily basis and total feed consumption per pen during the 33 day rearing period was calculated. Feed conversion was calculated as kg feed per kg weight gain. Lameness was assessed at 3, 4 and 5 weeks of age using a gait scoring method (Welfare Quality®, 2009; Kestin et al., 1992). Approximately 50 birds/pen were captured using the same procedure as for weighing and released from the smaller pen one by one. The birds´ walking ability was scored using a scale from 0 (perfect walk) to 5 (not able to walk).

4.1.3 Statistical analysis

Statistical analyses were performed using the program Statistical Analysis Systems (SAS version 9.4, SAS Institute Inc., Cary, NC). Statistical models were developed stepwise backward, i.e. starting with full models including all relevant available effects and interactions between effects followed by stepwise elimination of non-significant effects and interactions. The final models include the effects of treatments and biologically relevant and significant interactions of these effects.

4.2 Study II & III

The data from study II and III was collected during the same experiment. The objectives were to evaluate if changes of broiler activity, in response to the presence of a moving human, can predict the human-animal relationship in commercial broiler flocks (Study II) and to determine whether these changes were related to lameness (Study III).

4.2.1 Flocks and farms

The data for this experiment were collected from five European broiler farms (Italy, Spain, the Netherlands and two farms in the U.K) by five different assessors. Data were collected by from 16 flocks at 33 assessments occasions, at the ages of 3, 4 and/or 5 weeks.

4.2.2 Measures

The eYeNamic™ system was used to gather recordings of broiler activity. In this experiment only one of the system's four cameras (the camera mounted in the ceiling closest to the entrance) was used. The system delivered data on the activity of the animals with a sampling frequency of three recordings per minute. Activity was reported as an index between zero (no activity) and 100 (all bird pixels have moved between two consecutive frames), with increased animal activity giving an increasing index number (Kashiha et al. 2013).

The experimental procedure started with the collection of baseline activity for 10 minutes. No disturbance was allowed in the broiler flock during this period. After 10 minutes the assessor entered the animal house, walked along the side of the house, turned at the short side and walked in a straight line through the middle of the house below the camera (Figure 6). The aim was to, in a standardized way, mimic the farmer moving through the flock during the routine daily inspection. After the walking procedure, the flock was left alone without any disturbance for 15 minutes of activity recording. After this procedure assessments of human-animal relationship and lameness were carried out.

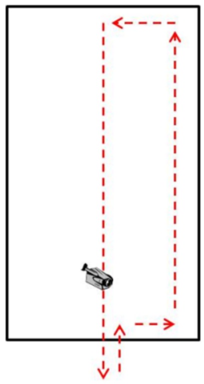

Figure 6. The standardized procedure of walking through the broiler flock.

The variables calculated from the activity recordings are presented in table 2.

Table 2. *Variables derived from the activity recordings.*

Variable	Definition
Baseline activity	Average activity index during 10 minutes before the assessor entered
Time to return to baseline (s)	Time from when the assessor left the house to when the animals resumed baseline levels of activity
Average activity after	Average activity during the time to return to baseline activity
Δ Amplitude	The difference between highest activity peak after assessor left the flock and baseline level

Study II

To assess the human-animal relationship the Touch Test (TT) (Graml et al., 2008) was applied. A trained assessor approached a group of at least three birds, crouched down close to the birds for 10 seconds and counted the number of broilers within an arm's length. The assessor then counted the number of birds that could be touched. This was done 21 times in every assessment session. The percentage of animals that could be touched (%) was calculated by dividing the number of touched birds by the number of birds which were within an arm's length.

Study II & III

The gait scoring method (Welfare Quality®, 2009; Kestin et al., 1992) was used to assess the birds´ walking ability. The bird's gait is observed and graded between 0 (perfect walking) to 5 (not able to move). At each assessment 100-200 birds were randomly selected and fenced in a portable arena, according to the WQ®- protocol.

4.2.3 Statistical analysis

The data were modelled using the multilevel statistical software package MLwiN (Rasbash et al., 2009). The multilevel structure of the data was specified within MLwiN as measurement occasion, within flock, within farm, and the outcome measure 'Percentage of birds touched' (Study II) and 'Gait Score' (Study III) were modelled using a GLM approach. Age, Δ Amplitude, Baseline activity, Average activity after, Time to return to baseline (and gait score in Study II) were all tested as covariates within the model. Those significant at $p \leq 0.05$ were retained in the final model.

4.3 Study IV

The objective with study IV was two folded, the first aim was to explore the economic potential of management practices intended to reduce broiler lameness, using a normative economic model. Secondly it was investigated through a survey how Swedish broiler farmers perceive these management practices.

4.3.1 Normative economic model

To estimate the economic impact of different production practices a partial budget based economic farm model was developed from earlier models (Dijkhuizen and Morris, 1997; Gocsik et al., 2014) and was adjusted to fit the characteristics of Swedish broiler production. The prevalence of lame birds (gait score ≥ 3) and its impact on productivity determined the economic impact of lameness. Four factors through which lameness may influence farm productivity and hence financial performance were included in the model. These factors were: increased mortality, increased feed conversion, increased condemnation rate at slaughter and decreased daily weight gain. The management practices selected for further analysis were: 1) an increased daily period of darkness (8 hours/day), 2) a decreased stocking density (27 kg/m2),

3) meal feeding (2-4 times per day), 4) restricted feeding, 5) sequential feeding and 6) feeding whole wheat (on average 30% of feed during the production period). Data on prevalence of lame birds and impact on production parameters were collected from the literature and the main economic inputs were gathered from a database (Agriwise, 2014). All calculations were made for a farm with a capacity of 80,000 chickens and it was assumed that one full time labour equivalent (FTE) is available at the farm.

4.3.2 Farmer´s perceptions of lameness and practices to control lameness

A questionnaire (Qualtrics Inc., Provo, UT) was sent to Swedish broiler farmers to explore their perceptions of problems associated with lameness and of the six management practices intended to control it (see the normative economic model). The questionnaire included basic questions about the farmer and the characteristics of the farm, one section with questions regarding the farmer's perception of the relevance and importance of lameness in his/her farm and a third section focusing on the farmer's thoughts on particular management practices intended to control lameness.

5 Results

This chapter summarizes the main results, for details see Paper I-IV.

5.1 Study I

The results from the Touch Test (TT), gait score (GS) and the production measures (live weight at slaughter and feed conversion ratio (FCR)) are presented in Table 3. Significant differences between the treatments were found regarding the human-animal relationship, with a higher percentage birds that could be touched in the Additional Human Contact groups. This was consistent from week 1 until week 4. At week 5 no difference could be found between the groups (Figure 7). Results are presented as Least Square Means ± Standard error.

Table 3. Comparison between the two treatment groups regarding Touch Test (TT), Gait Score (GS) and production measures (mean live weight at slaughter and Feed Conversion Ratio (FCR))

Measure	AHC	Control	p-value
TT (%)	81 ± 2.3	60 ± 2.3	< 0.001
GS	1.48 ± 0.05	1.39 ± 0.051	0.407
Weight	1.96 ± 49.7	1.97 ± 46.6	> 0.1
FCR	1.93 ± 0.017	1.92 ± 0.017	0.673

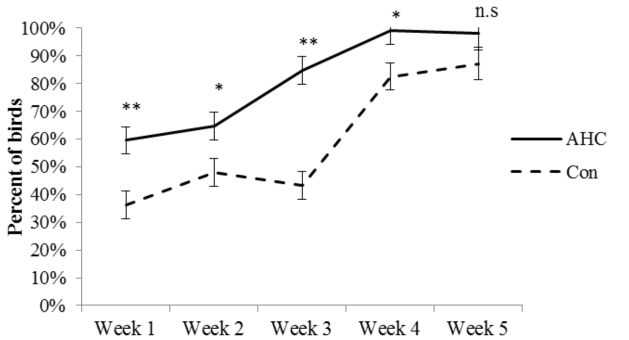

Figure 7. Differences in response to the Touch Test between additional human contact (AHC) and Control (Con) treatments at different ages (week 1-5). Least Square Means ± Standard error. N=56 tests. *** = p $\leq$0.001, ** = 0.01$\geq$p>0.001, * = 0.05$\geq$p>0.01, n.s. = not significant.

5.2 Study II & III

5.2.1 Activity recordings

Figure 8 shows a typical example of the recordings of activity. The presence of the assessor is clearly visible as an increased irregularity of the activity pattern. It is important to notice that the period when the human is present cannot be used for further calculations, since the eYeNamic™-system does not differentiate between 'human-pixels' and 'bird-pixels'. Hence the activity recordings when the human is in the house are a mix of bird and human movement. When the human has left the stable the reaction of the birds is visible as a characteristic downwards slope when the birds recover from the disturbance and return to baseline activity levels.

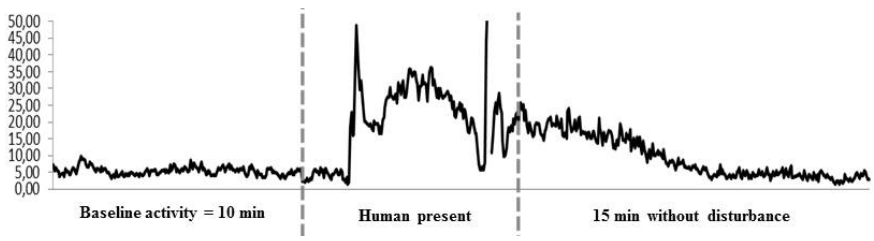

Figure 8. A representative example of activity pattern of a broiler flock during the experimental procedure. The striped lines indicate when the assessor entered and left the stable

5.2.2 Gait Score

In general, gait score means showed little variation over time and all the flocks had low GS scores (3 weeks =1.4±0.6, 4 weeks = 1.5±0.6 and 5 weeks = 1.9±0.6, (mean ± SD)), thereby showing good leg health status.

5.2.3 Prediction of Human-Animal Relationship and Lameness

The statistical analysis resulted in the following best predictive equation for % touched birds in the Touch Test:

$$Percentage\ touched\ TT\ (\%)_{ijk} = \beta_{0ijk}\, const + \beta_1 Age_{ijk} + \beta_2\, \Delta\, Amplitude_{ijk} + \beta_3 Baseline\ activity_{ijk} + \beta_4 Gait\ Score_{ijk}$$

Where Age, Δ Amplitude, Baseline activity and Gait score had significant effects on the outcome and are thus included in the equation.

The following equation can be used to predict Gait Score:

$$Gait\ Score_{ijk} = \beta_{0ijk}\ const + \beta_1\, \Delta\, Amplitude_{ijk} + \beta_2 Age_{ijk}$$

Δ Amplitude and Age were significantly related to Gait Score and are thus included in the equation.

The levels of an effect (*β*), the standard errors and p-values are presented in table 4 (Study II) and table 5 (Study III).

Table 4. *The parameter estimates of those variables that were found to be significantly associated with TT. Parameter estimates are given together with their standard error and significance.*

Variable	*β*	se	p-value
Constant	-30.218	16.695	-
Age (weeks)	10.900	3.076	0.0004
Baseline activity	-2.690	0.859	0.0018
Δ Amplitude	0.599	0.280	0.0324
Gait Score	18.350	7.937	0.0208

Table 5. *The parameter estimates of those variables that were found to be significantly associated with GS. Parameter estimates are given together with their standard error and significance.*

Variable	*ß*	se	p-value
Constant	1.045	0.269	< 0.001
Δ Amplitude	- 0.011	0.003	< 0.0002
Age	0.230	0.031	< 0.001

5.3 Study IV

5.3.1 Normative Economic Analysis

In terms of gross margin (return minus variable costs) the practises designed to reduce lameness (an increased daily period of darkness (8 hours/day), a decreased stocking density (27 kg/m2), meal feeding (2-4 times per day), restricted feeding, sequential feeding and feeding whole wheat (on average 30% of feed during the production period) all except restricted feeding did improve the financial performance of the broiler farm (Table 6). The model predicted the largest improvements in gross margin when the practices of feeding whole wheat, sequential feeding or meal feeding were applied. According to the theoretical calculations, feeding whole wheat, sequential feeding, meal feeding and longer dark period performed better than conventional practice when considering net return to management (return minus variable costs minus fixed costs). In contrast to the effect on gross margin, decreased stocking density and restricted feeding had lower net return to management than conventional practice.

5.3.2 Farmers' perceptions of lameness and practices to control lameness

The general conclusion from the outcomes of the questionnaire is that Swedish farmers do not perceive lameness as a big problem in their production. A majority of the respondents (N=9) did not regard it as a problem at all, four respondents regarded lameness as a minor (N=1) or a moderate (N=3) problem. Culling and impaired growth rate were referred to as the most adverse consequences of lameness. Eleven respondents estimated that between 0.1 - 0.7 % of the flock needs to be culled due to lameness (mean = 0.48%, ±0.58).

In general the respondents felt that the suggested practises (an increased daily period of darkness (8 hours/day), a decreased stocking density (27 kg/m2), meal feeding (2-4 times per day), restricted feeding, sequential feeding and feeding whole wheat (on average 30% of feed during the production period)) could not effectively control lameness. Results also illustrate the fact that lameness is considered as a complex problem and farmers believe that changing a single management factor may not be sufficient to reduce lameness.

Table 6. *Return, production costs, gross margin and net return to management for different lameness-reducing practices (values in SEK per kg delivered broiler)*

	Conventional	Longer dark period	Decreased stocking density	Meal feeding	Restricted feeding	Sequential feeding	Feeding whole wheat
Return	9.24	9.24	9.24	9.24	9.24	9.24	9.24
Variable costs	9.05	8.99	8.98	8.93	9.16	8.77	8.60
1-d old chick	2.17	2.20	2.13	2.27	2.28	1.97	2.14
Feed	5.44	5.34	5.44	5.16	5.38	5.47	5.03
Electricity	0.11	0.11	0.11	0.12	0.12	0.10	0.11
Heating	0.31	0.32	0.31	0.33	0.33	0.28	0.31
Catching & loading	0.32	0.32	0.31	0.33	0.34	0.29	0.32
Litter (straw)	0.04	0.04	0.04	0.04	0.04	0.03	0.04
Cleaning	0.16	0.16	0.16	0.17	0.17	0.14	0.16
Carrion collecting service	0.08	0.08	0.08	0.09	0.09	0.07	0.08
Environmental fee	0.01	0.01	0.01	0.01	0.01	0.01	0.01
General costs and insurance	0.05	0.05	0.04	0.05	0.05	0.04	0.04
Other	0.07	0.07	0.07	0.08	0.08	0.07	0.07
Mortality	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Condemnations	0.18	0.18	0.17	0.18	0.18	0.17	0.17
Fixed costs	1.72	1.73	2.07	1.76	1.77	1.78	1.71
Labour own	0.50	0.51	0.49	0.54	0.54	0.49	0.50
Depreciation	0.49	0.49	0.63	0.49	0.49	0.52	0.48
Maintenance	0.20	0.20	0.26	0.20	0.20	0.21	0.20

	Conventional	Longer dark period	Decreased stocking density	Meal feeding	Restricted feeding	Sequential feeding	Feeding whole wheat
Interest buildings	0.46	0.46	0.60	0.46	0.47	0.49	0.46
Interest working capital	0.07	0.07	0.10	0.07	0.07	0.08	0.07
Total production costs	10.77	10.72	11.05	10.69	10.93	10.55	10.30
Gross margin	0.19	0.25	0.26	0.31	0.08	0.47	0.64
Net return to management	-1.53	-1.48	-1.81	-1.45	-1.69	-1.31	-1.06

6 Discussion

In this thesis two welfare aspects of broilers have been investigated in detail; Human-Animal Relationship and Lameness. In Study I it was tested if it is possible to affect the human-animal relationship just by increasing the visual exposure of the broiler chickens to a human. The potential effect on productivity was also investigated. Instead of spot checks by an assessor, monitoring animal welfare during the whole rearing period gives a farmer the possibility to use the collected data as a management tool in his or daily care of the animals. Another issue with existing animal welfare assessment protocols is that assessment can be time consuming and costly. A travelling assessor may also put biosecurity at risk. Due to these arguments the possibility to assess human-animal relationship using automatic recording of bird activity was explored in Study II. The same methodology was investigated further in Study III to see if it could be used to assess one of the largest welfare issues in broiler production: lameness. In the final study, Study IV, the economic impact of improving lameness was modelled and the farmers´ perception of lameness and the economic aspects of improving it were explored. This chapter will present a general discussion of the main findings in these four studies. For details, see Paper I-IV.

6.1 Human-Animal Relationship

6.1.1 Modification of the human-broiler relationship

In study I the difference in the TT-results between the AHC- and control groups shows that additional human contact can improve the human-broiler relationship. The procedure presented in Figure 4, although constrained by the scale of the experimental situation, can be considered to mimic an everyday procedure when the stockperson walks several times through the flock. With the treatment groups subjected to a higher amount of human contact than is considered normal in practice. In this experiment, the control groups probably received more human contact than broilers in practice, since feed troughs had to be manually refilled, TT and GS were carried out and the birds got weighed by hand every week. This suggests that the effects on the human-animal relationship seen in Study I could have been even greater and that improvement of the human-animal-relationship is possible in commercial flocks. The main type of contact in Study I was visual, with the experimenter being in the pen and changing place with even intervals. The experimenter was allowed to talk gently to the animals, since that can happen in a real life situation during the daily check of the animals. This means that the contact to a certain degree also was vocal. The method presented in this study is not practical in commercial settings, but our findings do suggest that increased daily human contact could have a positive effect on the human-bird relationship, provided that the interaction is perceived as positive or neutral by the animals (Waiblinger et al., 2006). Of course, aversive human behaviours would likely have the opposite effect, resulting in elevated fear levels, stressed birds and impaired welfare (Waiblinger et al., 2006). The quality and frequency of interaction are important features of the management of broiler flocks.

6.1.2 Assessment methods

In both Study I and II the Touch Test (TT) as described by Graml et al. (2008) was used to assess the human-animal relationship. The method was developed to assess laying hens, however similar tests have been presented as suitable for broilers in welfare assessment schemes, such as the Welfare Quality®-protocol for poultry (Welfare Quality®, 2009), where an avoidance distance test is used to assess human-animal relationship. This supports that the Touch Test is a valid method and is suitable to use in commercial broiler houses.

However, the Touch Test could not be carried out in the high-density groups during the last week of the rearing period in Study I, because the crowded conditions restricted the birds' ability to move away from the experimenter. In Study I the birds were kept in $12m^2$ pens which restricted the available space for the birds. For experimental purposes, other assessment methods, such as a Stationary Person Test (Graml et al., 2008) where the birds are allowed to approach a person standing still in their environment, could be combined with or replace the TT to exclude the space as a limiting factor. Another consideration regarding use of the TT is that by incorporating an attempt to touch the birds it might mimic a predator encounter (Duncan, 1992) and thereby elicit greater fear. This could enhance the avoidance behaviour and push the assessment from a measure of human-animal relationship to a flight response from a potential predator. Locomotory difficulties are discussed by Waiblinger et al. (2006) as potential factors that may affect the results when using these types of tests to assess human-animal relationship. However, in both Study I and II the leg health status in the flocks was very good, which discards locomotory difficulties as a very influential factor in these two studies.

6.1.3 Human-Animal Relationship and the effect on productivity

The positive effects of a 'high quality' human-animal relationship on production parameters have been reported in several studies in a variety of livestock species. However, the broiler literature is more limited and the results are not always conclusive. For example Hemsworth et al. (1994) found a significant positive effect of human-animal relationship on feed conversion, but no effect on growth rate or mortality. The present study showed that regular human contact elicited clear improvements in the quality of the human-animal relationship but had no effects on the birds' production parameters. The differences in the human-animal relationship are most likely a result of different levels of habituation towards humans. It should also be remembered that simple, regular visual contact with a person are shown to be enough to reduce chicks' fear of humans (Jones, 1995) and that the control groups did receive some human contact here when stockpersons checked the flocks twice a day for food and water availability and the presence of sick birds. An assessor measured TT and GS once every week as well. This level of contact may also have improved performance and thereby dampened any treatment differences. Of course, negative human contact would be expected to have a negative effect on production parameters, e.g. young pigs that received unpleasant handling showed reduced growth (Hemsworth and Barnett, 1991).

The type of human contact applied in the present study (experimenter sitting down among the flock for 30 minutes a day) would not be practical in commercial conditions. However, since regular visual contact alone reduced fear of humans in chicks (Jones, 1993) and laying hens (Barnett et al., 1994) a more simplified regime of regular human contact might further enhance the development of a positive human-broiler relationship.

Although not addressed in the current studies, a good human-animal relationship that can be created by daily visits in the broiler flock can have positive effects when handling the birds, for example in connection with loading for transport or if unexpected maintenance or repairs needs to be done during the rearing cycle.

The present results are consistent with earlier findings that exposing broilers to regular human contact reduces their avoidance of an experimenter and thereby presumably improves the quality of the human-animal relationship. Further research on the effects of negative, neutral and positive human contact regimes on the human-animal relationship and the broilers' production performance and possible effect during handling in commercial conditions is clearly merited.

6.2 Lameness

6.2.1 The economic potential of reducing broiler lameness

One of the main objectives of Study IV was to explore the potential economic impact of implementing various alternative practices to reduce lameness in Swedish broiler farms. The alternative practices which realized the greatest improvements in gross margin and net return to management in the model were (in decreasing order): feeding whole wheat, sequential feeding and meal feeding. The improved economic performance related to these practices is mainly connected to lower feed price (wheat is cheaper than concentrate) and lower mortality rate that reduced production costs per delivered broiler. According to the economic calculations in study IV, farmers can profit from the inclusion of whole wheat in their feeding programs, but it must be realized that the price of wheat has a pivotal role in determining the level of potential profit.

6.2.2 Farmers´ perception of the prevalence and control of lameness

The positive economic potential of reducing lameness presented in Study IV was not expected as such by the respondents in the questionnaire. The main reason for this is probably the fact that the majority of farmers did not think about lameness as such a big problem in their production and thereby fail to see the added value in the presented methods. It should be emphasized that the current results were based on a small sample size and generalizing the results to a larger population, e.g., the whole Swedish broiler farmer population should be done with great caution (Flyvbjerg, 2006). However, the farmers' responses were quite coherent and offer a wealth of information on their considerations regarding lameness and alternative management practices.

6.3 Automatic welfare assessment

Performing a welfare assessment can be resource demanding, with regard to both time and money. The manual assessment protocols of today only give a snap shot of the welfare status at a given moment in time, usually in the end of a rearing period. This makes it impossible to use the data in the management of the current flock. The farmer can only use the information from the assessment to plan preventative actions in the next flock. A (semi) continuous assessing method gives the possibility to monitor the development of a potential welfare problem. This gives the farmer the possibility to detect welfare problems in an early stage and the opportunity to take mitigating actions. Moreover, an assessor needs to be trained, there are administrative tasks, and travel between livestock units also takes time. The visit of an assessor to different farms also presents a bio-security risk. The use of an automatic method, with the ability to assess continuously, could be a solution to this problem (Blokhuis et al., 2010).

6.3.1 Automatic assessment of human-animal relationship

The activity measures that turned out to have a significant effect on predicting the TT% in Study II were Δ Amplitude, Baseline activity, Gait Score and Age.

The Δ Amplitude is a measure of the birds' direct response to an approaching human. They move away from the human, which can be interpreted as fear of humans (Jones and Waddington, 1992). A higher level of fear in the flock is also represented by a lower percentage touched birds and therefore Δ Amplitude is present as a strong variable for predicting human-animal relationship.

Baseline activity, gait score and age are all closely associated with each other as shown by Weeks et al. (2000). The results from the study by Weeks et al. showed that general activity is highly affected by the age of the birds and the degree of lameness in the flock. The proportion of birds that spend their time lying down in the Week et al. (2000)-study was generally high (76-86%) and increased even more with both age and deteriorating walking ability.

Although the touch test is carried out in birds housed at a normal commercial stocking density, where there is sufficient space for a bird to move away from the observer if it wishes and is able to do so, the positive relationship between gait score and the percentage birds touched found here may at least partially reflect that a reduced walking ability makes it harder for the birds to move away from the human.

Since gait score and age is closely correlated (Kestin et al., 2001), this may explain the age effect as well, and the age effect may also be affected by the fact that the birds become habituated to humans (Waiblinger et al., 2006) during their lifetime.

The results from this study show the potential of using automatic image analysis techniques to assess the quality of the human-animal relationship in commercial broiler flocks. Such techniques can thus be of use in animal welfare assessment schemes.

6.3.2 Automatic assessment of lameness

The activity measures that significantly contributed to the prediction of the gait score in Study III were Δ Amplitude and age.

The variable Δ Amplitude is a measure of the birds’ direct avoidance response to the approaching human revealing the birds´ walking ability. The effect of age is consistent with previous reports (Sørensen et al., 2000, Weeks et al., 2000, Kestin et al., 2001) and is likely a side effect of the very rapid increase in live weight with age and lower general activity with increasing age (Weeks et al., 2000). The results in Study III demonstrate the potential value of using image analysis techniques for automated assessment of lameness in commercial broiler flocks.

Earlier studies show a prevalence of birds with gait score ≥ 3 varying from 15.6% (Bassler et al., 2013), 14.1- 26 % (Sanotra et al., 2003) to 57 % (De Jong et al., 2011) in fast growing hybrids. In both Study I and III in this thesis the prevalence of lameness was dramatically lower than the above mentioned (1.48 ±0.05 and 1.39±0.05 in Study I and 1.9±0.6 in Study III). This variation suggests that a larger scale inventory of the leg health status in commercial broiler production is desirable for future research.

6.4 Future developments

The relationships between technology derived data and the human-animal relationship and lameness that were found in this study show promise for the future development of a fully automatic assessment of these relevant welfare measures. Nevertheless, the results cannot be used in their present form to estimate the GS or TT in a random broiler flock since the models are fitted directly to the data and settings in these experiments, which could be seen as pilot studies. The performance of the models in other settings, where the background variability and range of the outcomes may be greater needs to be evaluated. .

A development of the results to fit commercial practice could be done on training data sets to investigate the variability. The data should be collected on similar farming systems, within a country or even within one farm on several flocks. The equations do contain two unknown variables which could be a problem in future development of these results. In the equations GS is used to adjust the TT score and in the other equation GS is used to estimate variables closely related to TT.

$$\textit{Percentage touched TT (\%)}_{ijk} = \beta 0_{ijk}\ \textit{const} + \beta 1\ \textit{Age}_{ijk} + \beta 2\ \Delta\ \textit{Amplitude}_{ijk} + \beta 3 \textit{Baseline activity}_{ijk} + \beta 4 \textit{Gait Score}_{ijk}$$

$$\textit{Gait Score}_{ijk} = \beta 0_{ijk}\, const + \beta 1\, \Delta\, Amplitude_{ijk} + \beta 2 Age_{ijk}$$

To adjust this effect in future development of the estimation of GS, it could be assumed that the contact between the flock and the stockperson on a given farm or within a production system is on a constant level.

7 Main conclusions

- Exposing broilers to regular human contact improves the quality of the human-animal relationship as measured by their avoidance of an experimenter. Further research on the effects of the human-animal relationship on the broilers' production performance and handling in commercial conditions is clearly merited.

- There is potential of using automatic image analysis techniques to assess the quality of the human-animal relationship and lameness in commercial broiler flocks and thus be of use as management decision making tools or in animal welfare assessment schemes. The predictive equations, presented in this thesis, are a first attempt to do this. The equations will need further development and be tested for validity and reliability, before they can be used on a larger, commercial scale.

- The results from this thesis indicate that some alternative practices (especially feeding whole wheat, sequential feeding and meal feeding) may not only improve broiler welfare by reducing the prevalence of lameness but may also enhance economic performance. Thus, if these practices are applied it could generate a win-win effect in terms of welfare and profitability.

8 Populärvetenskaplig sammanfattning

Modern kycklinguppfödning sker idag storskaligt med tusentals djur i samma flock. Detta skulle kunna resultera i att uppfödaren får färre möjligheter at övervaka alla individer i flocken. Samtidigt ställer samhället och konsumenterna större krav på att produkter med animaliskt ursprung har producerats med hög nivå på djurvälfärden.

För att förbättra välfärden för lantbrukets djur har flertalet protokoll och metoder för att mäta välfärd utvecklats. Welfare Quality®-protokollen är resultaten från ett projekt som startades 2004. Målet med projektet var att utveckla välfärdsbedömningsprotokoll som baseras på djurens beteende, hälsa och fysiska kondition och som gav en så korrekt uppskattning av djurens välfärdsstatus som möjligt. Problemen med de protokoll som utvecklades är bland annat att de är tidskrävande att utföra, bedömaren måste utbildas och därefter resa runt mellan gårdarna. Bedömningen ger också endast en bild av statusen just vid det enskilda tillfället, vilket kanske inte ger en rättvis bild av normaltillståndet hos djuren. En lösning på dessa problem vore att använda principerna från Precision Livestock Farming (PLF) och på så sätt nyttja automatisk teknologi för att bedöma välfärden. PLF och är ett relativt nytt forskningsområde där man med hjälp av avancerad teknik och sensorer övervakar och styr djurvälfärd, hälsa och/eller produktivitet inom djuruppfödning. I denna avhandling användes det så kallade EyeNamic™-systemet (Fancom BV), som består av kameror som monteras i taket på kycklingstallet. Dessa kameror är kopplade till ett datorprogram som baserat på bildanalytiska metoder automatiskt övervakar hur kycklingarna rör sig och hur flocken är fördelad i huset. Dessa två parametrar presenteras för uppfödaren i form av ett aktivitetsindex och ett distributionsindex. EyeNamic™-systemet möjliggör en kontinuerlig övervakning av kycklingarnas beteende, även när uppfödaren inte befinner sig i stallet och systemet kan larma ifall kycklingarnas beteende avviker från det normala.

I denna avhandling granskas två mätmetoder för att mäta välfärd hos kyckling i detalj; benhälsa och relationen mellan människa och djur. Benhälsan är en sedan länge känt välfärdsproblem bland kycklingar, även om frekvensen av djur med försämrad benhälsa har minskat betydligt de senaste åren. Vanligen bedöms benhälsan genom att utföra en så kallad Gait Score (GS), vilket är en typ av hältbedömning på en sexgradig skala (0-5, där 0 är perfekt gång och 5 innebär att kycklingen inte kan gå alls). Relationen mellan människa och djur är ur ett välfärdsperspektiv viktig, då en försämrad relation ofta bygger på rädsla och rädsla klassas som ett lidande hos djuren. Men relationen är också viktig både för köttkvaliteten och produktionsparametrar. Tidigare forskning har visat att en god relation mellan människa och en flock med kycklingar kan ha positiv effekt på första veckans dödlighet, foderkvot samt tillväxt. Relationen mellan människa och kyckling bedöms genom att på ett standardiserat sätt mäta avståndet mellan djuren och en människa som närmar sig (Touch Test, TT). Desto större avstånd, desto högre nivå av rädsla hos kycklingarna.

Resultaten av fyra olika studier presenteras i den här avhandlingen. I studie I undersöktes ifall kycklingarnas rädsla för människor kan reduceras genom regelbunden kontakt med människor och ifall denna relation påverkar produktiviteten. Resultaten visade att 30 minuter visuell kontakt med en människa (enligt en standardiserad rutin) 3 dagar per vecka signifikant förbättrade relationen mellan människa och djur. Inga skillnader mellan de grupper som fick extra mänsklig kontakt och de som fick minimal mänsklig kontakt kunde påvisas gällande produktionsparametrarna; levandevikt vid slakt eller foderkvot.

Studie II och III utfördes i fem kommersiella kycklingstallar i Italien, Spanien, Nederländerna och England. Samtliga stall hade sedan tidigare EyeNamic™-systemet installerat. Mätningar av benhälsa och relationen mellan människa och djur gjordes under 16 omgångar vid 3, 4 och 5 veckors ålder. I samband med detta utfördes även mätning av aktivitetsindex i flocken strax efter att en människa hade gått genom stallet (för att simulera den dagliga skötseln av djuren). Resultaten visade att nivån på djurens reaktion strax efter att människan hade lämnat stallet har ett nära samband med både benhälsa och relationen mellan djur och människa. Vilket i sin tur betyder att det är möjligt att utifrån aktivitetsindex i samband med den dagliga skötseln i stallet förutse benhälsa samt relationen mellan människa och djur. Metoden behöver dock utvecklas och testas i fler stallar innan den är redo att till fullo integreras i EyeNamic™-systemet.

Benproblem hos kycklingar innebär inte bara en försämrad välfärdsstatus, utan kan även ha negativa ekonomiska effekter i form av nedsatt produktivitet. I studie IV analyserades alternativa uppfödningsmetoder som förbättrar benhälsan och de eventuella ekonomiska konsekvenserna. Tidigare studier har visat att samband finns mellan höga nivåer av benproblem och förhöjd dödlighet och låga slaktvikter. Den ekonomiska analysen som presenteras i denna avhandling visar att alternativa metoder, såsom utfodring av helvete, sekvenserad utfodring och måltidsutfodring, både medför en förbättrad benhälsa och positiva ekonomiska effekter.

Sammanfattningsvis visar resultaten i denna doktorsavhandling att det finns potential i att använda automatisk kameraövervakning för att mäta relationen mellan människa och kycklingflocken och benhälsa hos kycklingar, samt att en god djurvälfärd i form av god benhälsa inte behöver påverka ekonomin negativt.

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Acknowledgements

This work was supported by the **Centre of Excellence in Animal Welfare Science**, a Swedish collaborative research environment. I would also gratefully acknowledge the European Community for financial support in Collaborative Project EU-PLF KBBE.2012.1.1-02-311825 under the Seventh Framework Programme where my study II and III were included.

My main supervisor, **Harry Blokhuis**, thank you for being committed to my research and for being supportive, especially when things have been delayed and affected my work in the most unexpected directions.
Thank you to my co-supervisor **Andy Butterworth**, for your quick answers to my questions and for sharing your expertise regarding poultry welfare with me.
Thank you to my co-supervisor, **Daniel Berckmans**, for always making me feel welcome to Leuven and for introducing me to the area of Precision Livestock Farming.

Anna Wallenbeck, a special thanks to you! You stepped in with your valuable advice and talent for problem solving when my projected needed it the most. Thank you for helping me with the statistics and for Sunday writing in combination with cuddling with lambs on the countryside!
Toby Knowles, thank you for your expertise and for your patience when explaining the mysteries of statistics to me.

I would like to thank the **personnel in the poultry stables** at the Swedish Livestock Research Centre in Uppsala for all the help with collecting production data. A special thanks to **Josefine Bjerking** for the help with the additional human contact-procedure.

Study II and III wouldn´t have happened without the **participating farms,** thank you very much! I would like to express my gratitude to **Déborah Temple, Ilaria Fontana, Gemma Richards, Henk Gunnink** and **Steven Brown** for carrying out the assessments. Thanks also to **Luc Rooijakkers**, **Eric Koenders** and **Tom van Hertem** at Fancom BV for technical support and for coordinating the video recordings.

I am thankful for the opportunity to participate as the 12th fellow in EU-Biobusiness project. Thank you to all the other fellows for the interesting scientific discussions, lectures and adventures; **Daniel, Hakim, Gunel, Maciej, Eduardo, Nancy, Andres, Lilia, Qin Tong, Tom** and **Stefano**.

I would like to thank **Amin**, **Ali** and **Alberto** at K.U. Leuven for supporting me within the technical field of image analysis.

I am grateful for the support and encouragement through the years from **Ragnar Tauson**, **Helena Wall** and all the others that work or have worked at HUV Fjäderfä. Thank you for introducing me to the wonderful world of poultry!

Thank you my fantastic colleagues at **HMH Uppsala** and **SCAW,** together we survived mouldy corridors in KC, a death smelling banana building and I really appreciate all the discussions (not always totally scientific ones…) during fika, lunch, dinners and parties.

Thanks to **Daiana, Elin** and **Anette**; my trusted "early lunch"-crew!
My lovely co-actor **Yezica**, if you ever feel the need to make another music video, don´t hesitate to call me! "The research will go on…"
Therese, thank you for making me smile and the support when I needed it the most (even thou you sent me into the dark caves of crazy cat ladies´ homes). You are always welcome to my and Johan´s home (but only if you wear an ugly Lantmännen-keps or a "foliehatt"). **Malin Alm**, my friend and my ally when it comes to nerdy poultry discussions. Thank you for two inspiring, challenging, taco-dinner filled and fun weeks in Denmark. Helga und Heidi forever <3 **Emma Ternman**, spending time with a person 24 hours/day in 5 days is the best way to get to know somebody. I am so happy that that somebody was you when we ended up as roomies in Brazil.

My fantastic PhD-colleagues need some extra attention! **Birgitte**, I am happy that I got the chance to get to know you, such an intelligent and fantastic person. I will forever miss Turbo´s "good morning"-sound in the Banana.

Thank you **Sofie** for crazy adventures in Flyinge, Lund and Sigtuna and for being a supportive “fadder”. **Malin**, what can I say… once you have shared a” bittergrotta” with a person the friendship will last forever!

Mina fantastiska föräldrar, **Yvonne** och **Roland**. Tack för att ni har låtit mig gå min egen väg och för att jag vet att jag alltid har ert stöd och kärlek.
Och ett extra tack för att ni har varit hundvakt de senaste 8 åren…
Tack **Linda**, världens bästa syster, raggarbilsrundor och stallhäng är en viktig grund i uppfostran av en lillasyster, bra jobbat! Min bror **Daniel**, tack för att du alltid ställer upp när man behöver dig! Jag har alltid roligt tillsammans med dig.

Min underbara make **Johan**.
Utan dig hade jag givit upp för länge sedan. Tack för att du pushar mig när jag som mest behöver det!

Jag älskar dig! 

Sist men icke att förglömma… Bästa sättet att ladda batterierna när energin tryter och hjärnan vill ta semester är att umgås med djur. Denna avhandling hade inte blivit till utan min allra finaste hjärte-hund **Enzo**. Eller ”mina” härliga hästar; **Varan, Crux, Vanadis, Vulcan, Vendela, Vintra, Valkyria, Vesuvius** och lilla **Vivann**.