MSc Thesis Business Economics

Economic optimization of animal welfare in the Dutch broiler sector using the Welfare Quality® assessment protocol for poultry

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Summary

The study described in this thesis was implemented within the context of increasing concerns about animal welfare in intensive farming systems. This trend is especially visible in developed countries. In the Netherlands, great attention is being paid to animal welfare in the pig and poultry sector. As a response, research has been done on how to assess animal welfare on farm. Additionally, economic studies have been performed to evaluate the financial viability of alternative animal production systems. The current study has been conducted to gain insight in the level of animal welfare in several Dutch broiler production systems. Furthermore, a cost analysis was done for each broiler production system type to gain insight in the costs of different production system types with a different level of animal welfare.

Several broiler production system types were included in the study, namely conventional, Volwaard, Puur & Eerlijk, extensive outdoor and organic broiler production. Since the Volwaard system and the Puur & Eerlijk system closely resembled each other, these two system types were treated as one system type in the analysis. For the analysis on animal welfare (AW), several system attributes were linked to welfare measures in the Welfare Quality® Assessment protocol for poultry (Welfare Quality®, 2009). Subsequently, the linkages were weighed to create allocation formulas. These formulas were used to determine Welfare Quality scores for each system attribute separately (attributional WQ scores) and for each broiler production system type (WQ Index scores). The cost analysis was based on the study of Gocsik et al. (2013). A deterministic model was used to calculate variable and fixed costs in Euros per delivered broiler. Moreover, total costs were calculated both per delivered broiler and per kg delivered broiler meat, to be able to compare the different production system types.

WQ Index scores were equal to 578, 736, 733 and 698 for the conventional system, the Volwaard and Puur & Eerlijk systems, the extensive outdoor system and the organic system, respectively. Thus, a sharp increase in WQ Index score was observed between the conventional system and the Volwaard and Puur & Eerlijk systems, while the WQ Index scores of the extensive outdoor system and the organic system were lower than the score of the Volwaard and Puur & Eerlijk systems but higher than the WQ Index score of the conventional system. The main contributors to the WQ Index scores of all system types were broiler type, stocking density and length of the dark period. Both variable and fixed costs increased when moving from the conventional system to the organic system. Total costs per kg broiler meat were equal to € 0.84, € 1.03, € 1.24 and € 2.01 in the conventional system, the Volwaard and Puur & Eerlijk systems, the extensive outdoor system and the organic system, respectively. Feed costs and costs for one-day-old chicks were main contributors to variable costs. With respect to fixed costs, labour costs were main contributor. Overall, the sharp increase in WQ Index score between the conventional system and the Volwaard and Puur & Eerlijk systems and the sharp increase in total costs between the extensive outdoor system and the organic system were remarkable. The sensitivity analysis showed that both trends were robust, but that sensitivity increased moving from the conventional system to the organic system.

Overall, it could be concluded that most can be gained in AW when shifting from conventional broiler production to the middle segment. Within the middle segment, little difference in broiler welfare was found, while a large difference in total costs per kg broiler meat was observed. However, the level of AW in relation to total costs of other broiler production system types (that were not included in the study) needs to be assessed to gain more insight in the middle segment. Moving beyond the middle segment did not significantly change AW, while total costs did increase considerably.

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List of abbreviations and definitions

ADT	Avoidance Distance Test; used to measure good human-animal relationship
Attributional WQ score	contribution of a specific attribute to the WQ Index score; the attributional WQ score is calculated by summing the multiplied welfare scores per measure and per barn with their defined weights
AW	animal welfare; the well-being of animals, that is influenced by welfare criteria
BB	breast blisters
FPD	foot pad dermatitis
HB	hock burn
Production system	aggregation of (AW influencing) attributes
QBA	Qualitative Behaviour Assessment; used to measure positive emotional state
System attribute	specific aspect of a production system, that relates to at least one welfare measure
System type	type of broiler production system; in the study, conventional, Volwaard, Puur & Eerlijk, extensive outdoor and organic were the included system types
Weight	the weight given to linkages between measures and attributes
Welfare criterion	'specific area of welfare concern that has to be addressed to satisfy good animal welfare' (Welfare Quality®, 2009)
Welfare measure	quantitative measure to assess a specific welfare criterion (Welfare Quality®, 2009)
Welfare Quality® (WQ) score	score that indicates how well an attribute of a specific production system satisfies animal welfare; the WQ score is calculated per barn by summing the welfare scores per measure of that barn
Welfare score	score that indicates how well an animal unit meets a welfare measure
WQ Index score	the mean WQ score of a specific system type

1 Introduction

Public awareness of animal welfare is increasing in the Netherlands, as is the case in many European countries. This trend can be observed in all animal sectors, but particularly in the broiler sector. The opinion of consumers and citizens is becoming increasingly important, and therefore is an essential aspect of sustainability of the broiler production process. Without consumer acceptance, continuity of the broiler sector can be hampered. Consequently, broiler farmers are expected to improve their production system regarding animal welfare. The sector has to maintain its "license to produce" (Te Velde et al., 2002).

As a response, several alternative broiler production system types have been developed that produce beyond the legal requirements. Between the conventional broiler production system and the organic broiler production system, a wide array of relatively new types of production systems exists (the "middle segment"). Currently, the largest share of the Dutch broiler production farms still is conventional production (Approximately 97%, Ellen et al., 2012). This is because the sector is mainly cost-price driven (Gocsik et al., 2013). Therefore, production has to be cost-effective. Alternative production system types generally produce at higher costs, and therefore can only survive when revenues per kg broiler meat are higher. As a result, these production system types produce for a niche market.

Research has been done using specific criteria that affect broiler welfare. Quantification of these criteria can be performed in the Welfare Quality® Assessment protocol for poultry (Welfare Quality®, 2009, further called "protocol") using a welfare score. Welfare criteria represent specific areas of welfare concern that have to be addressed to satisfy good animal welfare (Welfare Quality®, 2009), and are assessed based on at least one welfare measure. Most of the welfare criteria are measured on the individual broiler level.

While the protocol focuses on the individual animal level, broiler farmers focus on the production system as a whole. In the Netherlands, roughly three segments exist in broiler production, namely conventional broiler production, a middle segment and organic broiler production. Minimum legal requirements are set for the conventional broiler production system. Alternative broiler production system types produce at above legal requirements. Therefore, producing in this way is a voluntary decision by the farmer. The broiler production system types all have their specific standards regarding production system attributes. Within the context of this thesis, a system attribute is a specific aspect of a production system and is related to at least one welfare measure. The system attributes do take account for improvement in animal welfare, since they are based on scientific evidence. However, *real* differences are often not measured. Therefore, the system attributes are mainly based on *assumed* differences in animal welfare.

The main problem that broiler farmers are facing is the lack of information on animal welfare improvement and on additional costs of alternative broiler production system types compared to the conventional system, and the relation between both animal welfare and costs on system level. Information on the impact on animal welfare and on costs can help to economically optimize the farmers' decision making on animal welfare. From this, several research questions follow:

"What is the level of AW in the different broiler production system types?"
"Which system attributes are contributing to animal welfare and to which extent?"
"What are the costs of the broiler production system types?"
"Which cost items contribute most to total costs?"
"What is the relation between animal welfare and total costs, i.e. what is the cost-effectiveness of the different broiler production system types?"

The thesis is structured in the following way. Chapter 2 describes the methodology, starting with the general approach, followed by a description of Dutch broiler housing systems, an overview of welfare measures in the protocol and a description of the establishment of linkages and weights between system attributes and welfare measures. The Chapter ends with a description of the Welfare Quality model and the economic model used in the study. Chapter 3 presents the results, including both a separate analysis of Welfare Quality results and costs results and an analysis at which results of both the Welfare Quality and cost analysis are considered simultaneously. The Chapter ends with an extensive sensitivity analysis. Discussion on the methodology and results is presented in Chapter 4. The thesis ends with concluding remarks in Chapter 5.

2 Methodology

2.1 General approach

The main objective of the study was to evaluate several Dutch broiler production system types in terms of animal welfare (AW) and total costs. For this, the different production system types were analysed both with respect to AW and variable and fixed costs. Welfare scores can be calculated for all welfare measures using the Welfare Quality® Assessment protocol for poultry (Welfare Quality®, 2009, further called "protocol"). These welfare scores indicate how well an animal unit satisfies a welfare measure and can be used to calculate Welfare Quality (WQ) scores. The WQ score indicates how well an attribute of a specific production system satisfies animal welfare. Information on WQ scores of the system attributes (attributional WQ scores) was used to determine overall WQ scores (WQ Index scores) of the Dutch broiler production system types. A stepwise approach was used to obtain information on WQ scores and costs (Figure 1). In the study, the system boundary was at the level of the farm. This means that AW at slaughter and transport was excluded.

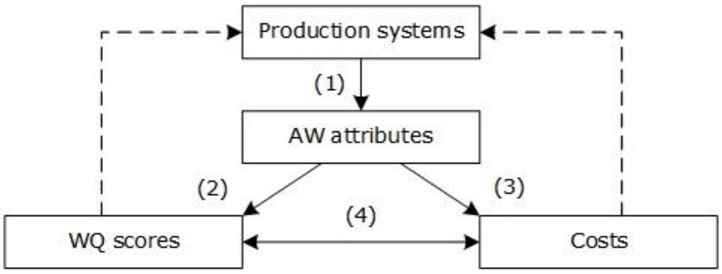

Figure 1. Overview of the research steps

A broiler production system can be regarded as an aggregation of system attributes that influence AW. Therefore, the first step was to decompose the various broiler production system types into multiple system attributes (step 1 in Figure 1). The system attributes used in the studies of Ellen et al. (2012) and Gocsik et al. (2013) were taken as starting point. It was decided to include the following ten system attributes in the analysis: broiler type, length of the growth period, weight at delivery, enrichment, % grain in the feed, stocking density, outdoor access, provision of daylight, length of the dark period and flock size.

Second, to be able to determine WQ scores for the system attributes (step 2 in Figure 1), the system attributes were linked to the welfare measures used in the protocol. This step was based on an extensive literature review. In case of conflicting findings or ambiguities, dr.ir. I. de Jong[1] was consulted on the issue. Since the formulas used in the protocol are criterion-based, it was not possible to apply these formulas in the study. This was because linkages were measure-based, and not all welfare measures that are used for a specific criterion were linked to a specific system attribute. Therefore, it was decided to give all linkages weights, based on literature review. These weights were used to create allocation formulas for transforming welfare scores that were calculated for each welfare measure into a WQ score for each system attribute. This step was somewhat arbitrary, since little research has been done on the magnitude of the impact of a specific system attribute on a welfare measure. Therefore, weighing was based on own interpretation of the literature and in consultation with dr.ir. I. de Jong. The allocation formulas were used to obtain attributional WQ scores. Subsequently, WQ Index scores could be calculated for each system type.

Third, costs were determined for each system type based on a deterministic model (step 3 in Figure 1). Cost calculations were performed to determine variable and fixed costs of the broiler production system types. Some research has been done on the financial impact of farm level adjustments in broiler production (Gocsik et al., 2013). This research served as base for cost determination.

[1] Wageningen UR Livestock Research, Lelystad; expert on amongst others animal welfare and contributor to the Welfare Quality® project.

Fourth, the obtained WQ Index scores and total costs were simultaneously analysed (step 4 in Figure 1). This was done for the different broiler production system types and included a sensitivity analysis, including an analysis on an organic variant with reduced feed costs and an analysis on the system attribute outdoor access.

2.2 Housing systems

As mentioned before, several alternative broiler production system types exist between the conventional broiler production system and the organic broiler production system. All broiler production system types have to be in line with the basic legal requirements set by the European Union (see Council of the European Union, 2007a). For the organic broiler production system, more stringent legislation has been set by the EU (see Council of the European Union, 2007b). Additionally, the Dutch government has set several stricter regulations (see PPE, 2004). The conventional broiler production system (further called "conventional system") can be regarded as the production system with minimum requirements. The organic broiler production system (further called "organic system") has to be in compliance with the most strict requirements. Regulations for the middle segment are given in PPE (2004). Besides, the Dutch market initiatives on alternative broiler production may formulate their own requirements (Ellen et al., 2012).

Next to the conventional and organic systems, three middle segment broiler production system types were included in the study, namely the Volwaard broiler production system (further called "Volwaard system"), the Puur & Eerlijk broiler production system (further called "Puur & Eerlijk system") and the extensive outdoor broiler production system (further called "extensive outdoor system"). Several other broiler production system types exist in the Netherlands (amongst others Gildehoen, Kemper Maïs scharrelkip, Kemper Landhoen and Polderhoen, Ellen et al., 2012). However, selection of production system types included in the study was dependent on available data. An overview of characteristics of the production system types included in this study is given in Table 1.

According to the Council Directive 2007/43/EC (Council of the European Union, 2007a), maximum stocking density is 33 kg/m^2 in the conventional system (without any additional requirements). If the farm can meet specific additional conditions, a stocking density of 39 kg/m^2 or even 42 kg/m^2 is allowed (Ellen et al., 2012). Per 24 hours, at least a 6 hours dark period is required, of which 4 hours should be uninterrupted (Ellen et al., 2012).

Table 1. Overview of characteristics of several Dutch broiler production system types

	System type				
Characteristics	Conventional	Volwaard	Puur & Eerlijk	Extensive outdoor	Organic
Broiler type	fast-growing	slow-growing	slow-growing	slow-growing	slow-growing
Length growth period (d)	40	56	56	56	70
Weight at delivery (g)	2,200	2,300	2,300	2,100	2,600
Daily growth (g/d)	57[1]	41[2]	41[2]	38[3]	37[2]
FCR (g feed/g weight)	1.70	2.09	2.09	2.15	2.60
Mortality (%)	3.7	2.5	2.5	2.8	2.8
Stocking density (kg/m^2)	33 - 42	31	25	27.5	21
Outdoor access	n.a.	covered	covered	uncovered 1 m^2/broiler	uncovered 4 m^2/broiler
Daylight provision	no	no	yes	yes	yes
Minimum length dark period	6h	6h	8h	8h	8h
Minimum % grain in feed	-	70	70	70	-
Provision of grain or straw	no	yes	yes	yes	yes

Based on Ellen et al. (2012), unless another reference is given
[1] (KWIN-V, 2013-2014); [2] (Gocsik et al., 2013); [3] own estimation

Little difference exists between the Volwaard and Puur & Eerlijk systems. The Puur & Eerlijk system keeps the broilers at a lower stocking density and the minimum length of the dark period is longer compared to the Volwaard system. Moreover, provision of daylight is obligatory in the Puur & Eerlijk system, in contrast to the Volwaard system. All other characteristics are similar between these two system types. Both system types have a covered veranda, which is not regarded as outdoor access in the protocol. During data collection, not all Volwaard and Puur & Eerlijk farms already had a covered veranda. In the Welfare Quality model, the score for outdoor access was set equal to zero. In the cost analysis, costs of the covered veranda were included for the Volwaard and Puur & Eerlijk systems.

In the organic system, at least 95% of the feed has to be of organic origin, and roughages have to be provided (Ellen et al., 2012). Organic production faces a maximum flock size of 4,800 broilers and a maximum barn size of 1,600 m^2 (Ellen et al., 2012). Additionally, a SKAL certificate is needed to produce organic broiler meat. SKAL is a Dutch organization that audits organic farms.

2.3 Overview of welfare measures in the Welfare Quality® Assessment protocol for poultry

In the protocol, the welfare measures are grouped under several welfare criteria. These criteria all represent a specific area of AW. This section gives an overview of the welfare criteria and the corresponding welfare measures. Each heading starts with the specific welfare criterion, followed by the corresponding welfare measures.

Criterion 1 and 2. Absence of prolonged hunger and absence of prolonged thirst: Emaciation and drinker space

Emaciation and drinker space are welfare measures used to quantify the criteria absence of prolonged hunger and absence of prolonged thirst, respectively. However, all Dutch broiler farmers are required to give access to feed and water constantly due to regulation, irrespective of the system type (see Council of the European Union (2007a) and PPE (2004) for European and Dutch regulation, respectively). The one exception is that periodical feeding may be applied in the conventional system. Water should be provided unrestricted in all system types, and no regulation exists on number of birds per drinker.

Criterion 3. Comfort around resting: Plumage cleanliness, litter quality and dust sheet test

The broilers' feathers are useful not only in providing isolation but also for protection against skin infections. When feathers are soiled, they lose their protective properties, that can result in reduced welfare (Welfare Quality®, 2009). Litter quality is particularly related to management and to a lesser extent to system type. However, some system attributes do have influence on the ease of maintaining good litter quality, like length of the growth period and stocking density.

Criterion 4. Thermal comfort: Panting and huddling

Two types of thermal discomfort exist, namely hypothermia or cold stress and hyperthermia or heat stress. The former is expressed by broilers that are huddling, while the latter is expressed by panting. Both types of stress are defined by effective environmental temperatures that lie outside the thermo-neutral zone of the broilers; below the lower critical temperature (LCT) or above the upper critical temperature (UCT), respectively (Widowski, 2010). While hypothermia can be a problem for young chicks, hyperthermia is the main thermal discomfort faced by broilers (EFSA, 2010). Particularly fast growing broilers frequently appear to struggle with heat stress (e.g. Ahmad and Sarwar, 2006). Additionally, high stocking densities can increase the environmental temperature. Hypothermia is less common in the Netherlands, but can occur in extensive broiler flocks. Slow growers are generally more resistant to both cold and heat stress than fast growing broilers (Widowski, 2010). Therefore, slow growing broilers kept at low stocking densities generally are less sensitive to cold stress than fast growing broilers kept at high stocking densities are for heat stress.

It has to be noted that, even when broilers have adopted thermoregulatory mechanisms, it is unclear whether their welfare is impaired or not. Multiple behavioural studies done by Morrison and McMillan (1985; 1986) and Morrison et al. (1987) have indicated that broilers change their thermoregulatory mechanism even when exposed to small deviations from the thermo-neutral zone. However, the point in temperature at which broilers really experience discomfort is unclear (Widowski, 2010).

Criterion 5. Ease of movement: Stocking density

The ease of movement criterion is about animals having enough space to be able to move around freely (Welfare Quality®, 2009). This criterion is reflected by stocking density as welfare measure. Stocking density was also defined to be an important system attribute.

Criterion 6. Absence of injuries: Lameness, hock burn, foot pad dermatitis and breast blister

The main cause of lameness is skeletal problems (EFSA, 2010). Lameness is an important welfare aspect since it can influence welfare directly due to pain and indirectly due to restrictions in expressing certain behaviours. Discussion exists as to whether pain or biomechanical limitation causes abnormal gait (Corr et al., 2003; EFSA, 2010). But even if there is disagreement, it is clear that lameness affects broiler welfare in a way, since lameness can result in specific restrictions (e.g. not being able to reach the feeders or drinkers). Lameness is mostly related to genetics, but the broilers' environment can also influence occurrence and severity of lameness. The scoring system that is used in multiple studies and also in the protocol is the Bristol Gait Scoring System (BGSS). This scoring system is developed by Kestin et al. (1992). Scores range from zero to five, where a score of zero means a normal gait and a score of five means unable to walk. A gait score of three or more reflects reduced broiler welfare (EFSA, 2010).

Contact dermatitis is a generic term for foot pad dermatitis (FPD), hock burn (HB) and breast blister (BB). It is an ulcerative condition of the skin affecting the plantar surface of the feet (FPD), the hock (HB) or the breast (BB) (Haslam et al., 2007). All three conditions have known a serious rise in occurrence in European broiler production (Bessei, 2006). However, prevalence of contact dermatitis is decreasing during the past few years, amongst others due to European monitoring (see Council of the European Union, 2007a) and genetic selection against it (EFSA, 2010). According to Bessei (2006), it is evident that contact dermatitis causes pain. Therefore, it is an important welfare issue. It is reflected as a nonallergic inflammatory reaction of the skin to an external substance (Frosch and John, 2011), like ammonia.

Criterion 7. Absence of disease: On farm mortality, culls on farm, ascites, dehydration, septicaemia, hepatitis, pericarditis and abscess

Mortality can be an important indicator of broiler welfare. However, it is the difference between birds found dead and birds culled that really matters. Culling can be divided in voluntary and involuntary culling. Voluntary culling means that broilers unsuitable for raising and slaughtering are killed (EFSA, 2010). Involuntary culling means that broilers suitable for production are suffering from poor welfare, and therefore are killed (EFSA, 2010).

Mortality itself is not necessarily a welfare problem. It is about the way a broiler dies, i.e. the extent of suffering the broiler undergoes before dying or the time it takes to die (EFSA, 2010). High levels of mortality can thus reflect poor broiler welfare. Contrarily, high levels of culling can reflect the best way to prevent broilers from suffering (EFSA, 2010). Nonetheless, both culling and mortality should be kept at a minimum level.

Ascites occurs under conditions of increased oxygen demand (EFSA, 2010). It is a condition that is expressed as fluid accumulation in the abdomen, pulmonary congestion and oedema (EFSA, 2010). So, ascites is not a disease but a metabolic disorder that can be lethal. Since the 1990s, ascites has been brought under control by both management approaches and genetic selection (Cahaner in EFSA, 2007). This is reflected by the sharp decrease in occurrence of ascites in Dutch flocks. In slow growers, prevalence is approximately equal to zero, while in fast growing broilers, ascites does occur, but prevalence is low (dr.ir. I. de Jong, personal communication, 2014).

Criterion 8 and 9. Absence of pain induced by management and expression of social behaviours
To date, no welfare measures have been developed to quantify these criteria. Additionally, the criterion absence of pain induced by management is completely related to farm management and not to system type. The effect of system type on social behaviours could consequently not be assessed.

Criterion 10. Expression of other behaviours: Cover on the range and free range
The criterion expression of other behaviours is measured by the estimated percentage of covered range and the estimated percentage of birds outdoors (corresponding to the welfare measure free range).

Criterion 11. Good human-animal relationship: Avoidance Distance Test (ADT)

The Avoidance Distance Test (ADT) assesses the number of birds within arm's length of the assessor. The distance reflects the level of fear the animals have for humans. The criterion reflects the notion that animals should be handled well in all situations (Welfare Quality®, 2009).

Criterion 12. Positive emotional state: Qualitative Behaviour Assessment (QBA)
The Qualitative Behaviour Assessment (QBA) measures the quality of the animals' behaviour and interaction with the environment and each other (Welfare Quality®, 2009). This criterion reflects the notion that negative emotions such as fear and distress should be avoided whereas positive emotions such as security should be promoted (Welfare Quality®, 2009).

2.4 Establishment of linkages and weights between system attributes and welfare measures

2.4.1 Linkages and weights

As mentioned before, the formulas in the protocol are criterion-based, and therefore could not be applied in the study. No clear linkage could be found between welfare criteria and system attributes. Therefore, linkages were measure-based. Consequently, weights had to be given to all linkages to create allocation formulas for calculating WQ scores. Table 2 gives an overview of the linkages between system attributes and welfare measures. Linkages are denoted by an 'X'. Shaded cells represent the adaptations that were made following expert opinion (dr.ir. I. de Jong). When an 'X' is shown within the shaded cell, the linkage between the corresponding system attribute and welfare measure could not be supported with literature. When the shaded cell is empty, some literature was found to support the linkage, but it was decided to remove the linkage (as was the case at the welfare measures huddling, septicaemia and pericarditis). The numbers in front of the welfare measures correspond to the numbers given in the protocol. Welfare measures that could not be linked to at least one of the system attributes are not shown in the matrix.

During literature study it was found that some linkages were more profound than others. For some welfare measures, this tendency was not found, and therefore, all linkages with these specific welfare measures obtained equal weights. Other welfare measures did show a more thorough relation with one or more system attributes compared to other linked system attributes. The weighing procedure included several steps and was implemented as follows. First, for each welfare measure, the linkages were evaluated on their relative importance. When a linkage was least profound, it obtained an importance factor of one. In case of a more strong relation between a welfare measure and a system attribute, the linkage obtained an importance factor of two and in case of a direct relation between a welfare measure and a system attribute, the linkage received an importance factor of three. So, the relative importance increased with an increasing factor value.

For the establishment of allocation formulas, the sum of the weights of all linkages for each welfare measure had to be equal to one. Therefore, the importance factors were transformed into weights. An overview of the weights between system attributes and welfare measures is given in Table 3. For convenience, the numbers in front of the welfare measures were replaced with integer values. The welfare measures huddling, septicaemia and pericarditis were removed from the matrix, since they could not be linked to any system attribute (and therefore were empty in Table 2).

Table 2. Matrix showing linkages between system attributes and welfare measures

	System attributes									
Welfare measures	A1. Broiler type	A2. Length growth period	A3. Weight at delivery	A4. Enrichment	A5. % Grain in feed	A6. Stocking density	A7. Outdoor access	A8. Daylight	A9. Length dark period	A10. Flock size
3.1: Plumage cleanliness						X	X			
3.2: Litter quality		X				X		X	X	
4.1: Panting	X					X				
4.2: Huddling										
5.1: Stocking density						X				
6.1: Lameness	X	X		X		X		X	X	
6.2: Hock burn	X	X	X			X			X	
6.3: Foot pad dermatitis	X				X		X		X	
6.4: Breast blister	X									
7.1: On farm mortality	X						X		X	
7.3: Ascites	X								X	
7.5: Septicaemia										
7.7: Pericarditis										
10.2: Free range							X			
11.1: ADT[1]									X	X
12.1: QBA[2]				X		X		X	X	X

[1] Avoidance Distance Test

[2] Qualitative Behaviour Assessment

Table 3. Matrix showing weights between system attributes and welfare measures

	System attributes									
Welfare measures	A1. Broiler type	A2. Length growth period	A3. Weight at delivery	A4. Enrichment	A5. % Grain in feed	A6. Stocking density	A7. Outdoor access	A8. Daylight	A9. Length dark period	A10. Flock size
1. Plumage cleanliness						0.50	0.50			
2. Litter quality		0.20				0.40		0.20	0.20	
3. Panting	0.50					0.50				
4. Stocking density						1.00				
5. Lameness	0.22	0.22		0.11		0.11		0.11	0.22	
6. Hock burn	0.20	0.20	0.20			0.20			0.20	
7. Foot pad dermatitis	0.25				0.25		0.25		0.25	
8. Breast blister	1.00									
9. On farm mortality	0.33						0.33		0.33	
10. Ascites	0.67								0.33	
11. Free range							1.00			
12. ADT[1]									0.67	0.33
13. QBA[2]				0.33		0.17		0.17	0.17	0.17

[1] Avoidance Distance Test

[2] Qualitative Behaviour Assessment

The remainder of this section will elaborate on the linkages and weights measure-wise.

1. Plumage cleanliness

The welfare measure plumage cleanliness was linked to the system attributes stocking density and outdoor access. Plumage cleanliness is indirectly related to stocking density through litter quality. High stocking density can reduce litter quality (Bessei, 2006). Consequently, high stocking density can result in less plumage cleanliness. No supportive literature was found on the linkage between plumage cleanliness and stocking density and outdoor access. However, the relation between both was found to be important enough to include in the study.

Since the linkage with stocking density was indirect, and no literature was found to support the linkage with outdoor access, it was decided to give both linkages an importance factor of one. This resulted in equal weights of 0.5.

2. Litter quality

Litter quality was linked to four system attributes: length of the growth period, stocking density, provision of daylight and length of the dark period. According to Bassler et al. (2013), litter quality goes down with increasing flock age. As already noted at plumage cleanliness, litter quality can be reduced due to high stocking density (Bessei, 2006). Bailie et al. (2012) found that daylight has a positive effect on litter quality. Additionally, Bassler et al. (2013) found a negative correlation between dark period length and litter quality; a long dark period was related to bad litter quality. They speculate that this is due to reduced bird activity. Since broilers mainly rest during the dark period (Calvet et al., 2009), they compact the litter instead of working it (Bassler et al., 2013).

The linkage with stocking density was evaluated as being most important, and therefore received an importance factor equal to two compared to the other linkages. The relation between length of the dark period and litter quality was given an importance factor of one, since this is not a direct link but has to do with decreased activity of the broilers. The linkages with length of the growth period and provision of daylight both obtained an importance factor equal to one too. This resulted in a weight of 0.4 at the linkage between litter quality and stocking density, and weights of 0.2 at the other three linkages.

3. Panting

Two system attributes were linked to panting, namely broiler type and stocking density. Sandercock et al. (2006) concluded from their experimental study that increased growth rate has compromised the broilers' ability to cope with high temperatures. In this study, a broiler line was compared to a layer line. Widowski (2010) and EFSA (2010) state that hyperthermia is more problematic in fast growing broilers compared to slow growers. The relation between broiler type and hypothermia is unclear. Studies of Sandercock et al. (2006) and Widowski (2010) indicate that fast growing broilers face more difficulty in coping with both hot and cold temperatures compared to slow growing broilers. Contrarily, the lower muscle growth of slow growers results in less body isolation and could therefore increase the broilers' susceptibility to low temperatures. Since huddling is only occurring occasional and in low frequencies within the flock, it was decided to exclude the linkage between broiler type and huddling from the analysis. According to EFSA (2010) and Bessei (2006), high stocking densities can result in hyperthermia. This is especially noticeable in warmer climates. Hyperthermia is expressed by an increased respiration (panting) (EFSA, 2010). A high stocking density can result in an increased ambient temperature. The effect of high stocking densities can be reduced by proper ventilation.

Since the occurrence of panting is mainly due to high ambient temperatures, the welfare measure is more related to the environment and to a lesser extent to genetics and stocking density. Broiler type, together with insufficient ventilation on broiler height (dr.ir. I. de Jong, personal communication, 2014) enhances the effect of high temperatures on panting (EFSA, 2010). The same holds for stocking density. Therefore, both welfare measures received an equivalent importance factor of one, that resulted in equal weights of 0.5.

4. Stocking density

Stocking density is a striking welfare measure, since it was also defined to be one of the system attributes. High stocking density reduces freedom of movement (Bessei, 2006; Dawkins et al., 2004). Since the linkage with the system attribute stocking density was the only one, it received a weight equal to 1.

5. Lameness

As mentioned before, lameness is an important AW issue. This was also reflected by the fact that many supportive literature was found, and consequently many linkages could be made. Lameness was linked to the system attributes broiler type, length of the growth period, enrichment, stocking density, provision of daylight and length of the dark period. Genetic selection on fast growth rate has had an adverse effect on several broiler welfare aspects (Savory, 2010). One main aspect is increased susceptibility to lameness (Butterworth and Weeks, 2010; EFSA, 2010). In fast growing broilers, high growth rate differs between the different body parts (Havenstein et al., 2003). It can result in skeletal anomalies like leg disorders (Butterworth and Weeks, 2010; Corr et al., 2003; Lilburn, 1994). Moreover, selection for increased breast muscle size resulted in biomechanical disadvantages owing to the width of the breast (Butterworth and Weeks, 2010). Overall, it can be stated that high growth rate is a main cause of leg weakness.

According to Bassler et al. (2013) and Knowles et al. (2008), flock age is a risk factor for lameness, that supports the linkage with length of the growth period. Kells et al. (2001) showed that broilers in houses enriched with straw bales were more active than broilers in unenriched houses. This activity was reflected by spending more time on locomotion, drinking and standing, while less time was spent on sitting and resting. There was no effect on time spent on feeding. Stimulation of broiler activity can improve leg health, thereby reducing lameness (Bailie et al., 2012). Effect of enrichment on other health aspects is negligible (Butterworth and Weeks, 2010).

Hall (2001) and Sørensen et al. (2000) state that with increasing stocking density, lameness increases in both prevalence and severity. Knowles et al. (2008) found a relation between gait score and stocking density too. An explanation can be that the amount of free floor space available for the broilers decreases with increasing stocking density, thereby increasing lameness (Butterworth and Weeks, 2010). This is supported by Bizeray et al. (2000), who state that less exercise increases leg problems.

From the study of Bailie et al. (2012) it followed that broilers kept at daylight showed lower average gait scores than broilers kept without daylight. Length of the dark period was found to influence lameness too, as followed from the studies of Bassler et al. (2013) and Knowles et al. (2008). A longer dark period resulted in reduced fear of humans and a reduction of lameness.

The linkages between lameness and broiler type, length of the growth period and length of the dark period were evaluated as being most profound and therefore received an importance factor equal to two relative to the other linkages. Genetic factors are the main contributors to leg disorders (EFSA, 2010; Whitehead et al., 2003). Bassler et al. (2013) analysed the effect of the length of the dark period on several broiler welfare issues. However, they did not only assess whether there was a relation, but also the magnitude of the effect on the issues. The effect of increasing dark period was high for lameness.

Lameness is mainly influenced by management practices (EFSA, 2010). Good management can reduce occurrence and severity of lameness substantially, even at very high stocking densities. The linkages with enrichment, stocking density and provision of daylight were evaluated as being of less importance and therefore were given an importance factor equal to one. Overall, it followed that the three more important linkages received a weight of 0.22, while the other three linkages received a weight of 0.11.

6. Hock burn

Hock burn (HB) was linked to almost the same system attributes as lameness. This can be explained by the fact that HB and lameness are partly related to each other. Kjaer et al. (2006) found that HB had a higher incidence in fast growing broilers compared to slow growing broilers. Hepworth et al. (2011) also state that HB is influenced by overall growth rate. Haslam et al. (2007) found that a younger slaughter age is related to reduced HB, that underpins the relation with length of the growth period.

Kjaer et al. (2006) and Hepworth et al. (2010; 2011) found a positive correlation between body weight at slaughter and HB. Kjaer et al. (2006) found a difference in prevalence of HB at a difference in body weight at slaughter of 900 g. In practice, body weight at delivery lies within the range of approximately 2100 g to 2600 g (a difference of 500 g, however, slaughter weights most often lay far below 2600 g). Therefore, the studies of Hepworth et al. (2010; 2011) better reflect reality, since they used real farm data and thus found a difference in HB at a more realistic range in body weight. However, since real data was used instead of an experimental setting, influences of other factors have to be considered. Hepworth et al. (2011) suggest that fast growers reach a weight that exceeds the capacity of the house earlier and therefore may require different management. This capacity is not only reached in terms of space but also in litter quality, and thus an environment that could stimulate HB is created sooner.

The relation between HB and stocking density is complex. A study of Hepworth et al. (2010) showed that a negative association existed between HB and stocking density at placement, that means that a higher stocking density was related to a reduced prevalence of HB. Contrarily, another study has shown a positive association between stocking density at placement and contact dermatitis (Buijs et al., 2009). However, the latter was an experimental study, using very small pens with a maximum of 72 birds per pen. Since many environmental differences can exist between such small pens and large pens in broiler farms, extrapolation of the results to large pens has to be done carefully. The study of Hepworth et al. (2010) did show a positive correlation between HB and stocking density at five weeks.

Calvet et al. (2009) state that the prevalence of HB decreases with increasing dark period length. Contrarily, Bassler et al. (2013) found no correlation between dark period and HB.

No clear difference in importance of the linkages was found. HB is more related to environment than to genetics (and thus broiler type). Additionally, it could be concluded that it is likely that a relation between body weight at delivery and HB exists in reality, but this relation had to be handled with care in the analysis. As holds for lameness, HB is mainly influenced by management practices too (EFSA, 2010). Therefore, HB can be reduced markedly by improved management, even at high stocking densities. From the study of Bassler et al. (2013) followed that the effect of increasing dark period was relatively low for HB. Overall, all linkages received an equal importance factor and therefore were given an equal weight of 0.2.

7. Foot pad dermatitis

Foot pad dermatitis (FPD) could be linked to four system attributes: broiler type, percentage of grain in the feed, outdoor access and length of the dark period. Decreased locomotor activity, and thereby spending more time in a sitting or lying posture, is also related to high growth rate (Bessei, 2006; Bokkers and Koene, 2003). This, together with poor litter quality, can result in FPD (Bessei, 2006). Kjaer et al. (2006) found a higher incidence of FPD in fast growing broilers (just as was the case for HB).

According to Mayne (2005), wet litter is the main factor affecting FPD, followed by biotin deficiency. Grains such as barley and wheat generally have a low biotin availability (Waldenstedt, 2006). Use of whole grains in the diet reduces the absolute nutrient intake, that can result in insufficient daily intakes of several critical nutrients (Waldenstedt, 2006). Contrarily, Knowles et al. (2008) found that not feeding whole weed is associated with high gait scores, and stated that this is in line with studies of Brickett et al. (2007) and Su et al. (1999), who analysed the impact of nutrient density and meal feeding versus feed restriction, respectively. Knowles et al. (2008) state that this relation was possibly found because feeding whole wheat can result in reduced growth rate, due to the slower rate of digestion for whole wheat. Moreover, increasing the amount of grain in the feed can positively influence the gastrointestinal tract of the broilers, thereby resulting in more consistent dropping (dr.ir. I. de Jong, personal communication, 2014). This can, in turn, improve litter quality, and thus have a positive influence on

FPB. Contrarily, Shepherd and Fairchild (2010) state that nonstarch polysaccharides are found in higher concentrations in grains like wheat and barley compared to soybean meal. These indigestible and 'sticky' carbohydrates increase gut viscosity, that results in less consistent droppings (Shepherd and Fairchild, 2010). As a result, litter quality can decrease and the manure can stick more readily to the birds' feet. These contradicting findings could suggest that FPD is both related to the independent effects of nutrition (relating to the percentage of grain in the feed) and litter quality and to a combined effect of both.

A survey performed in the UK showed that outdoor access was related to a higher prevalence of FPD (Pagazaurtundua and Warriss, 2006). Both the highest prevalence and the highest severity were found in the organic system. Bassler et al. (2013) and Calvet et al. (2009) found a decreased prevalence of FPD at increased length of the dark period.

As is the case at HB, no clear difference in importance of the linkages could be found at FPD. All forms of contact dermatitis (HB, FPD and BB) are mainly related to environmental factors and to a lesser extent to genetics (EFSA, 2010). The effect of the percentage of grain in the feed on FPD is not straightforward, since literature is contradictory. The effect of the length of the dark period on FPD was relatively low (Bassler et al., 2013). The four linkages each received the same importance factor and consequently obtained a weight of 0.25.

8. Breast blister

Breast blister (BB) was linked to broiler type. As was already mentioned, high growth rate is related to decreased locomotor activity (Bessei, 2006; Bokkers and Koene, 2003), that can increase BB (due to more sitting and lying). Since BB was only linked to one system attribute, the linkage obtained a weight equal to 1.

9. On farm mortality

Three linkages were obtained for on farm mortality, namely broiler type, outdoor access and length of the dark period. According to EFSA (2010), increased mortality is associated with fast growing broilers. Little research has been done on the relation between outdoor access and mortality. While mortality could be higher in flocks with outdoor access due to predation, two Polish studies show that the opposite holds (Mikulski et al., 2011; Skomorucha et al., 2008). Rozenboim et al. (2010) state that mortality is higher for flocks with a short dark period compared to flocks with a relatively long dark period (23L:1D compared to 16L:8D).

Again, no distinct inequality could be found with respect to the importance of the linkages. Consequently, all three linkages were evaluated as being of equal importance and therefore all obtained a weight of 0.33.

10. Ascites

Ascites was linked to broiler type and length of the dark period. Selection on high growth rate has resulted in an increased susceptibility to several metabolic disorders (Havenstein et al., 2003). Butterworth and Weeks (2010) state that an unbalanced genetic selection of fast growing broilers has resulted in disorders associated with abnormal metabolic function. Frequently more than one tissue or organ is affected. These disorders arise due to an imbalance between production rate and maintenance requirements (Scheele, 1997). An increased oxygen demand at fast growth rates can put pressure on the cardio-pulmonary system (De Greef et al., 2001; Druyan and Cahaner, 2007). As a consequence, many fast growing broilers face metabolic disorders like ascites (Bessei, 2006; Butterworth and Weeks, 2010). According to Gordon (1997) an increased dark period may reduce ascites.

Since the relation between ascites and broiler type seemed to be more clear, this linkage was given an importance factor of two, while the linkage with length of the dark period was given an importance factor equal to one. Genetic factors contribute highly to metabolic disorders like ascites. The relation between dark period and ascites was only speculative. This resulted in weights of 0.67 and 0.33 for broiler type and length of the dark period, respectively.

11. Free range

Free range is a welfare measure that is directly translated in the system attribute outdoor access (just as stocking density was defined both as welfare measure and as system attribute). Since free range was only linked to outdoor access, the linkage received a weight equal to 1.

12. ADT

The Avoidance Distance Test (ADT) was linked to length of the dark period and flock size. A longer dark period resulted in reduced fear of humans and a reduction of lameness (Knowles et al., 2008). Bassler et al. (2013) also found that dark period length influenced the results of ADT. Large flock size corresponded to increased fear and stress levels compared to small flocks (Rodenburg and Koene, 2007). The study of Bassler et al. (2013) showed that the effect of dark period length on ADT is relatively high. Therefore, this linkage received an importance factor equal to two, while the linkage with flock size received an importance factor of one. This resulted in weights of 0.67 and 0.33, respectively.

13. QBA

The Qualitative Behaviour Assessment (QBA) was linked to enrichment, stocking density, provision of daylight, length of the dark period and flock size. Kells et al. (2001) studied the effect of enrichment with straw bales on activity and behaviour. As already mentioned at the linkage between lameness and enrichment, broilers in enriched houses were more active than broilers in unenriched houses. An interesting result of the study was that the time spent on all recorded behaviours (except feeding) was not only visible in broilers that were interacting with the straw bales, but also in broilers that were not in close proximity to the bales. So, next to a direct effect of the bales on activity in the way that broilers perform behaviours like pecking at them and jumping upon them, there was an indirect effect on activity such that, even away from the bales, there was more activity. These results also show that low levels of activity are not only caused by physical incapacity (Kells et al., 2001) but also by environmental enrichment. EFSA (2010) also states that a barren environment hampers behavioural expression of broilers.

Moreover, high stocking densities can hamper behavioural expression, particularly at the end of the growth period (EFSA, 2010). Daylight has little effect on health but positively influences behavioural rhythms (Blatchford et al., 2009). Bailie et al. (2012) also found a positive influence of daylight on multiple behaviours. Bassler et al. (2013) found that dark period length influenced the outcome of the QBA, just as was the case at ADT. At last, flock size was found to be related to QBA (Rodenburg and Koene, 2007). Effect on aggressive behaviour is limited, and fearfulness is also affected by housing type (Rodenburg and Koene, 2007).

Literature seemed to be more confident on the interaction between QBA and enrichment than on the relation between QBA and the other three system attributes. High stocking densities can reduce expression of behaviours, that can reduce positive emotional state of broilers (EFSA, 2010). However, it concerns a hypothesis, since no reference is given to a study. Additionally, it is stated that the reduction in behavioural expression is most likely to happen in the last week of the broilers' life. The relation between QBA and dark period length was somewhat unclear too. Whether dark period length had a positive or negative influence on the broilers' wellbeing (expressed as the outcome of QBA) could not be said (Bassler et al., 2013). To conclude, the linkage with enrichment received an importance factor of two, while the other four linkages were given an importance factor equal to one. Consequently, the weight for the linkage with enrichment was 0.33, while the weights for stocking density, provision of daylight, dark period length and flock size were equal to 0.17.

2.4.2 Comments

Most problems with respect to broiler welfare are caused by multiple factors, roughly divided in genetic factors and environmental or management factors (Bessei, 2006). Additionally, an interaction effect exists between these factors (Bessei, 2006). However, it is recognized that some problems are mainly related to genetic factors and others are mainly related to environmental or management factors (EFSA, 2010). Moreover, little information exists on interaction effects with respect to broiler welfare, because of a focus on productivity and reproduction instead of on welfare in relevant studies (EFSA, 2010). Therefore, it was decided to create allocation formulas without interaction effect.

No system attributes were linked to the welfare measures emaciation and drinker space. This can be substantiated by the fact that both are related to farm *management* and not to the specific farm *system types*. Regulation is (almost) similar between the system types. Therefore, both welfare measures were excluded from the analysis.

The amount of dust was not related to any system attribute. It is possibly related to length of the growth period and stocking density, but no literature has been found to support this. Amount of dust is highly related to another welfare measure, namely litter quality. This again supports the finding that not all individual welfare measures are unrelated to each other.

Imaeda (2000) states that high stocking density causes cardiovascular disorders, like septicaemia and pericarditis due to an increase in stress. However, due to genetic selection against cardiovascular disorders over the past few years, prevalence of such disorders has decreased considerably (dr.ir. I. de Jong, personal communication, 2014). No recent literature is available on the prevalence of cardiovascular disorders. Also, no data was available on the prevalence of cardiovascular diseases. Therefore, it was decided to exclude the linkages between stocking density and septicaemia and pericarditis.

Dehydration, septicaemia, hepatitis, pericarditis and abscess all can be assessed at slaughter, together with ascites. However, all diseases but ascites could not be linked to a system attribute. Some have been found to be linked with stocking density and/or broiler type (e.g. septicaemia and pericarditis) (Imaeda, 2000), but due to genetic selection, prevalence of these diseases does not differ between fast and slow growing broilers anymore (dr.ir. I. de Jong, personal communication, 2014).

Increased on farm mortality is associated with faster growth rates probably mainly due to the increased susceptibility to metabolic diseases. One important metabolic disease, that can be lethal, is ascites. However, other metabolic diseases like SDS (sudden death syndrome) are not directly included in the protocol. The main reason for this is that often no records are kept with respect to these diseases. When broilers are found dead or are culled in the farm or rejected in the slaughterhouse, the specific reason is often not clear. Additionally, some diseases are only diagnosable when the broilers are examined post mortem. Since these diseases do have great influence on welfare (EFSA, 2010), mortality figures can be used as an indicator of the prevalence and severity of diseases. According to Bokkers and de Boer (2009), mortality can be regarded as the consequence of a “failing biological-adaptation mechanism. Mortality, therefore, is an indirect or cumulative animal welfare indicator.” However, the relation between on farm mortality and animal welfare is ambiguous. Culling sometimes is the best way to prevent broilers from suffering (EFSA, 2010). Since mortality figures also include culling, high mortality rates can partly reflect good management and improved welfare. In conclusion, both the numbers of and the ratio between culling and broilers found dead is important. Unfortunately, the culling percentage of total mortality is often not recorded.

Outdoor access could also be related to contagious and parasitic diseases, but these diseases are not applied in the protocol, and therefore could not be assessed. If it would be possible to include this relation in the analysis, it would have negatively influenced total WQ Index scores of the system types with outdoor access compared to the WQ Index scores of the system types without outdoor access. Also no data was available on the percentage of covered range for the different system types. Therefore, this welfare measure could not be included in the analysis.

2.5 Welfare Quality model

2.5.1 Model

A step-wise approach was used to obtain a WQ Index score for each system type (Figure 2). First, welfare scores per welfare measure and per animal unit were calculated (step 1 in Figure 2). Calculations were done following the protocol, except for mortality and rejections. For these two welfare measures, welfare scores were calculated based on De Jong et al. (2011). Next, WQ scores were determined per system attribute (step 2 in Figure 2). These attributional WQ scores were calculated multiplying each linked welfare score with their defined weight, and subsequently adding the obtained weighed scores:

$$WQ\text{-}A_{jk} = \sum(w_{ik} * x_{ij}) \quad (1)$$

where $WQ\text{-}A_{jk}$ *= attributional WQ score for animal unit j (j = 1...180) and system attribute k (k = 1...10, where 1 = broiler type, …, 10 = flock size),*
w_{ik} *= weight of the link between welfare measure i (i = 1…13, where 1 = plumage cleanliness, …, 13 = QBA) and system attribute k,*
x_{ij} *= the welfare score on welfare measure i and animal unit j.*

To obtain the attributional WQ scores per system type, the mean of the attributional WQ scores of the animal units of that specific system type was determined (step 3 in Figure 2):

$$WQ\text{-}A_{km} = \sum(WQ\text{-}A_{jk}) / n \quad (2)$$

where $WQ\text{-}A_{km}$ *= attributional WQ score for system type m (m = 1…4, where 1 = conventional, …, 4 = organic),*
n = number of farms of system type m.

Subsequently, the mean attributional WQ scores were summed to determine the WQ Index score per system type:

$$WQ\text{-}I_m = \sum WQ\text{-}A_{km} \quad (3)$$

where $WQ\text{-}I_m$ *= WQ Index score for system type m.*

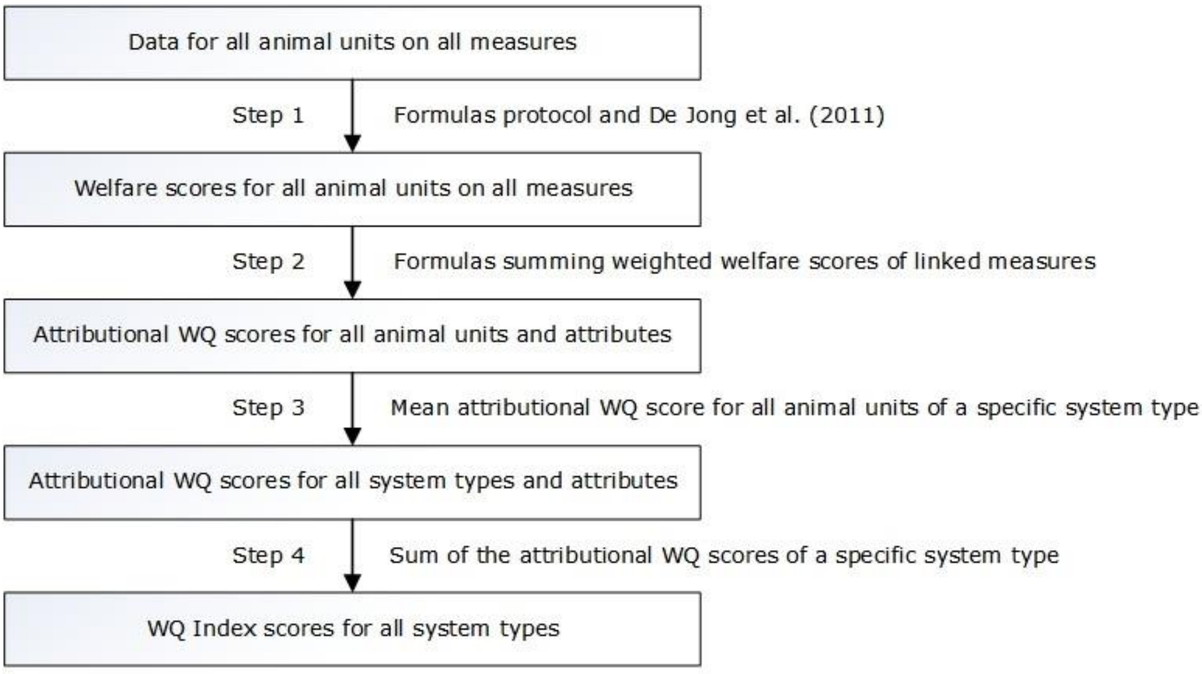

Figure 2. Overview of the stepwise calculations

Subsequently, a one-way ANOVA was used to compare attributional WQ scores and WQ Index scores of the four system types. Normality was tested and held for all welfare measures. However, the Levene's test showed significant values for most of the welfare measures, indicating that variances are unequal. Moreover, large differences existed in sample size. Therefore, a Games-Howell significance test[2] was used for significance testing of attributional WQ scores and WQ Index scores.

2.5.2 Data

Animal welfare data was collected within the Welfare Quality® project. The database included data assessed in 180 animal units in the Netherlands, the United Kingdom, Italy and Belgium, that were used to calculate welfare measures. The database included 140 conventional, 28 Volwaard and Puur & Eerlijk, 10 extensive outdoor and 2 organic animal units. Relevant data were gathered in an SPSS Statistics Data Document (IBM Corporation, NY). Subsequently, data were used to calculate individual welfare scores per welfare measure per animal unit. For all calculations, farm data were used. Only in cases where no farm data were available, slaughter plant data were used. This was the case at breast blisters and rejections.

Since the Volwaard system and the Puur & Eerlijk system could not be distinguished from each other within the dataset, these two system types had to be evaluated together. As mentioned before, these two system types only differ slightly from each other, so no inconvenience was experienced with respect to WQ score and cost calculations.

Data was available for all welfare measures except for ascites. Ascites is a welfare measure that can only be recorded in the slaughter plant. While the cause of rejection is determined and total rejection figures are preserved, most slaughter plants do not store information on the proportions of causes. As a result, total rejection figures are present and specific causes are known, but the proportion of rejection due to ascites is unknown. Additionally, figures could only be found in the study of Gocsik et al. (2014). In this study, prevalence figures of ascites were estimated for different system types. For conventional, Volwaard and Puur & Eerlijk, system types with two stars of the Better Life label and organic, prevalences were estimated to be equal to 3.3% (Maxwell and Robertson, 1998), 1.7%, 1.7% and 0% (Scheele et al., 2005), respectively. System types with two stars of the Better Life label are comparable to the extensive outdoor system. However, the dataset used in the study showed rejection figures that were on average lower than the estimated prevalences of Gocsik et al. (2014). Percentage of rejections ranged from 0% to 5.54% with a mean of 0.47%. Overall, it could be concluded that no clear picture could be drawn on the prevalence of ascites in the different system types. Since rejections were already relatively low in the dataset, it was decided to use the rejection figures in the dataset to approximate prevalence of ascites. Mean rejection prevalences were equal to 0.51%, 0.49%, 0% and 0% in the conventional system, the Volwaard and Puur & Eerlijk systems, the extensive outdoor system and the organic system, respectively.

Negative values for plumage cleanliness were set equal to zero, just as had to be done at QBA according to the protocol. For plumage cleanliness, this method is not prescribed. However, it was determined to use this approach based on expert opinion (dr.ir. I. de Jong, personal communication, 2014).

In the protocol, the welfare measures cover on the range and free range were quantified as the estimated percentage of covered range and the estimated percentage of birds outdoors, respectively. Cover on the range exists of vegetation or manmade shelters (Welfare Quality®, 2009). Both welfare measures are only applicable to the extensive outdoor system and the organic system. Consequently, scores could be calculated for these system types only. For the conventional system and the Volwaard and Puur & Eerlijk systems, the scores with respect to both welfare measures were set equal to zero. Thus, these welfare measures were zero for the system types with covered veranda too.

[2] The Games-Howell significance test is a pairwise multiple comparison procedure that can deal with unequal variances and unequal sample sizes (Wilcox, 1987). Tests that do assume equal variances (e.g. Tukey or LSD) are not robust to violations of this assumption (Games et al., 1983).

The welfare measure cover on the range is described in the protocol, but subsequently no formula is given to calculate welfare scores for this welfare measure. Since it was unclear how this welfare measure influences broiler welfare, it was decided to exclude this welfare measure from the analysis. Although it is expected that an increase in cover on the range results in an increase in AW, it could also be possible that an optimum exists in the percentage of covered range. Where this optimum lies is unclear. For example, twenty percent cover could be sufficient for the broilers, and ninety percent cover would be both non-realistic and could be worse with respect to welfare than lower percentages. Overall, since insufficient knowledge on this aspect existed, the welfare measure was excluded.

2.6 Economic model

2.6.1 Model

Costs were calculated for all four system types separately using a deterministic model. The model was based on the research of Gocsik et al. (2013). For all fixed costs and for several variable costs formulas were used to calculate values. An overview of these cost formulas is given in Appendix I. Variable costs, fixed costs and total costs were determined in Euros per delivered broiler. Additionally, total costs in Euros per kg broiler meat of the production system types were determined to be able to compare the different system types.

Since the market for alternative broiler meat is relatively new and thus still developing, price levels can severely be affected by changes in supply and demand (Gocsik et al., 2013). Therefore, a higher level of risk is present on the market for alternative broiler meat regarding prices. Due to these fluctuating and uncertain prices, the current study was limited to costs of the production system types. Thus, revenues were not included. However, the costs do give an indication on the revenues per delivered broiler and per kg meat needed to break even. For an indication on revenues, see Gocsik et al. (2013).

2.6.2 Data

The model used predefined prices and technical variables to calculate variable and fixed cost items. Table 4 summarizes prices (price premiums are shown between brackets) and technical variables that were used to characterise the four system types. One-day-old chick prices and feed prices for the conventional system were retrieved from KWIN-V (2013-2014). For the alternative system types, the same price premiums were used as in the study of Gocsik et al. (2013).

Healthcare costs for the system types using a slow growing breed were estimated to be 80% of the costs of health care of the fast growing breed (Gocsik et al., 2013). Healthcare costs for the conventional system were set equal to € 0.045 per broiler and consequently, costs for the alternative system types were equal to € 0.036 per broiler. Litter costs per broiler were set equal to € 0.008 and for the alternative system types, costs for provision of grain and straw was added. Heating costs were set equal to € 0.045 per broiler and for the alternative system types additional heating costs were estimated due to the covered veranda or outdoor access. Water costs were set equal to € 0.008 per broiler. For the organic system, water costs were doubled. Costs for electricity were set equal to € 0.023 and halved for the organic system. General costs included a fee of the PPE (Dutch Product Board for Poultry and Eggs) and costs for cadaver collection. Manure costs were assumed to be equal to zero for the organic system, due to the high demand for organic manure (Bokkers and de Boer, 2009; Gocsik et al., 2013). For the organic system, the SKAL control fee was included. The organic system benefits from a lower interest rate than the other system types ("green interest") (Gocsik et al., 2013). Interest rates for the organic system and the other system types were equal to 4% and 5%, respectively.

Table 4. Prices and technical variables used in the economic model

	System type			
	Conventional	Volwaard Puur & Eerlijk	Extensive outdoor	Organic
Prices[1]				
One-day-old chick price (€/broiler)	0.32	0.34 (+6%)	0.34 (+6%)	0.46 (+45%)
Feed price (€/100 kg)	29.50	28.61 (-3%)	28.61 (-3%)	41.89 (+42%)
Technical variables				
Animal places (#)	90000	66600	46275	25000
Density at placement (kg/m2)	43.56	31.09	28.14	21.5
Light roof	no	yes	yes	yes
Covered veranda	no	yes	no	no
Outdoor range	no	no	yes	yes
Outdoor area required (m2/animal)	0	0	1	4
Breed	fast-growing	slow-growing	slow-growing	slow-growing
Weight at delivery (g)	2200	2300	2100	2600
Length growth period (d)	40	56	56	70
Daily growth (g/d)	55	41.07143	37.5	37.14286
Empty barn period (d)	10	10	10	10
Rounds/year (#)	7.3	5.530303	5.530303	4.5625
FCR (g feed/g weight)	1.69	2.09	2.25	2.6
Mortality (%)	3.7	2.5	2.8	2.8
Delivered broilers (#/yr)	632691	359110	248749	110869
Delivered broilers (kg/yr)	1391920	825954	522373	288259
Extra activities				
Provision of grain/straw	no	yes 2 g/d from wk 2 (33 d)	yes 2 g/d from wk 3 (26 d)	yes
Labour				
Total labour required (# working hours/yr)	2348.78	2348.03	2348.02	2349.00
Total labour available (# working hours/yr)	2349.00	2349.00	2349.00	2349.00
Difference	0.22	0.97	0.98	0.00

[1] price premiums are shown between brackets

3 Results

3.1 Welfare Quality results

Table 5 presents the mean welfare scores per system type for all linked welfare measures. Additionally, the trends in welfare scores on all welfare measures when moving from the conventional system to the organic system are shown in Appendix II.

Table 5. Mean welfare scores per welfare measure and per system type

	System type			
Welfare measures	Conventional	Volwaard Puur & Eerlijk	Extensive outdoor	Organic
Plumage cleanliness	25.2	7.0	3.8	35.9
Litter quality	36.0	84.0	7.6	50.5
Panting	73.8	98.9	100.0	100.0
Stocking density	22.4	58.3	70.8	55.0
Lameness	8.7	19.5	20.6	17.8
Hock burn	35.7	67.1	83.4	42.6
Foot pad dermatitis	26.0	75.7	52.5	5.3
Breast blister	66.8	63.7	91.6	49.4
On farm mortality	62.9	58.7	71.2	60.9
Ascites	80.4	79.2	100.0	100.0
Free range	0.0	0.0	44.0	44.0
ADT[1]	87.3	44.0	34.4	47.6
QBA[2]	52.8	80.0	52.9	89.0
Total welfare score	578.0	736.0	732.7	698.0

[1] Avoidance Distance Test

[2] Qualitative Behaviour Assessment

Results of the Welfare Quality (WQ) score calculations are given per system type in Table 6 and Figure 3. The total WQ score reflects the WQ Index score. Shifting from the conventional system to the Volwaard and Puur & Eerlijk systems showed a sharp increase in WQ Index score. However, when moving on to the extensive outdoor and organic systems, a limit was reached regarding WQ Index scores. Appendix III gives an overview on the trends in attributional WQ scores when moving from the conventional system to the organic system, in which system attributes were sorted based on their relative contribution to the WQ Index score (starting with the system attribute with the highest contribution). Different trends can be observed regarding the changes in attributional WQ score when moving from the conventional system to the organic system. The system attributes stocking density and length of the growth period roughly show the same trend as the overall trend on the WQ Index score. Moreover, restrictive system attributes could be designated, which explained the obtained limit in the system types with outdoor access (the extensive outdoor system and the organic system). These were flock size, enrichment and provision of daylight in the extensive outdoor system, broiler type and weight at delivery in the organic system, and stocking density, length of the dark period, length of the growth period and percentage of grain in the feed in both system types. The system attribute outdoor access was the only attribute that was not restrictive in both the extensive outdoor system and the organic system.

The main contributors to animal welfare (AW) in all system types were (in decreasing order) broiler type, stocking density, length of the dark period and outdoor access. Total contribution of these four system attributes ranged from 79% to 86% of the total WQ Index score. Several causes could be ascribed to the high contributions of these system attributes. First, all four system attributes were linked to a relatively large amount of welfare measures (broiler type and stocking density were both linked to seven welfare measures, length of the dark period to eight welfare measures and outdoor access to four welfare measures). Moreover, high contribution of each system attribute to the WQ Index score was due to several specific linkages with welfare measures.

Table 6. Mean attributional WQ scores per system type

	System type			
	Conventional	Volwaard Puur & Eerlijk	Extensive outdoor	Organic
Broiler type	193.8[a]	222.2[b]	266.3[c]	200.1[a]
Length growth period	16.3[a]	34.5[b]	22.8[c]	22.6[abc]
Weight at delivery	7.1[a]	13.4[b]	16.7[c]	8.5[a]
Enrichment	18.6[a]	28.8[b]	19.9[ab]	31.7[ab]
% Grain in feed	6.5[a]	18.9[b]	13.1[b]	1.3[c]
Stocking density	103.2[a]	173.8[b]	153.5[b]	168.5[b]
Outdoor access	40.1[a]	42.0[a]	82.8[b]	83.6[b]
Daylight	17.0[a]	32.3[c]	12.6[a]	26.9[bc]
Length dark period	137.6[a]	142.1[a]	124.7[a]	124.1[a]
Flock size	37.9[a]	28.0[b]	20.3[b]	30.7[ab]
Total (WQ Index score)	578.0[a]	736.0[b]	732.7[b]	698.0[ab]

[a-c] Significance test: Games-Howell, alpha = 0.05

The attributional WQ scores of broiler type increased significantly when shifting from the conventional system via the Volwaard and Puur & Eerlijk systems to the extensive outdoor system and dropped considerably in the organic system (Table 6). The high WQ scores of broiler type were mainly due to the relatively high welfare scores on the welfare measures panting (ranging from 74 to 100) and ascites (ranging from 79 to 100, Appendix II). Furthermore, the sharp increase could be ascribed to the high weights given to panting (w = 0.5), breast blister (BB, w = 1) and ascites (w = 0.67). The drop in the organic system could be explained by the contribution of the welfare measures hock burn (HB), foot pad dermatitis (FPD) and BB.

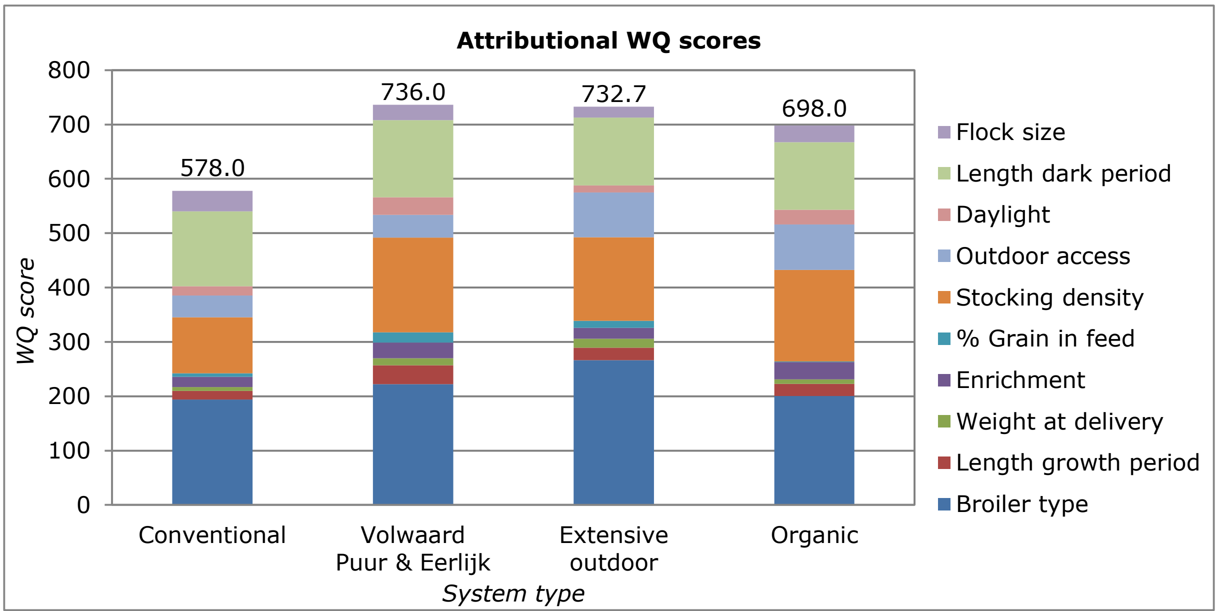

Figure 3. Contribution of the system attributes to the WQ Index scores per system type

The attributional WQ scores of stocking density fluctuated when moving from the conventional system to the organic system (Table 6). First, a significant increase occurred between the conventional system and the Volwaard and Puur & Eerlijk systems. Then, a decrease when moving from the Volwaard and Puur & Eerlijk systems to the extensive outdoor system and an increase when moving from the extensive outdoor system to the organic system was shown, but both were non-significant. This trend was mainly due to the high weight given to the welfare measure litter quality in combination to the highly fluctuating trend of this welfare measure (Appendix II). Additionally, the high contribution of the system attribute stocking density to the WQ Index score was due to the high weights on panting (w = 0.5) and stocking density (w = 1) and the high welfare scores of panting.

The attributional WQ scores of the system attribute length of the dark period showed a steady trend, where the individual WQ Index scores of all different system types did not differ significantly (Table 6). The high attributional WQ scores were mainly due to the high welfare scores of on farm mortality and ascites (Appendix II).

The system attribute outdoor access showed a different trend. The attributional WQ scores of the conventional system and the Volwaard and Puur & Eerlijk systems were almost equal to each other, just as was the case for the extensive outdoor system and the organic system (Table 6). However, shifting from the Volwaard and Puur & Eerlijk systems to the extensive outdoor system showed a significant increase in attributional WQ score, at which the score was roughly doubled. The high WQ Index scores of the extensive outdoor system and the organic system were essentially attributable to the high welfare scores of the welfare measure free range (Appendix II) and the corresponding high weight (w = 1).

Most welfare measures were linked to multiple system attributes. As a result, differences in contribution of a system attribute between system types were not only due to differences in the system attribute itself (like kg/m^2 for the system attribute stocking density) but also due to other (environmental) differences. For example, a score for panting is not only influenced by broiler type, but also by stocking density. If there would be no influence of other system attributes, the contribution to AW of for example broiler type would be equal for the system types with slow growing broilers. However, information on the interactions between system attributes was lacking and therefore an additive model was used.

To obtain insight in which system attributes were contributing most to the difference in WQ Index scores between system types, the changes in contribution of the system attributes to the WQ scores compared to the conventional system were determined (Figure 4). Not all system attributes had the same impact on attributional WQ scores. Most system attributes contributed positively to the attributional WQ scores when moving from the conventional system to an alternative system type. Contrarily, some of the system attributes had a negative contribution on the attributional WQ scores compared to the conventional system. This held for the system attribute provision of daylight in the extensive outdoor system, for the system attribute length of the dark period in both the extensive outdoor system and the organic system, and for the system attribute flock size in all three alternative system types.

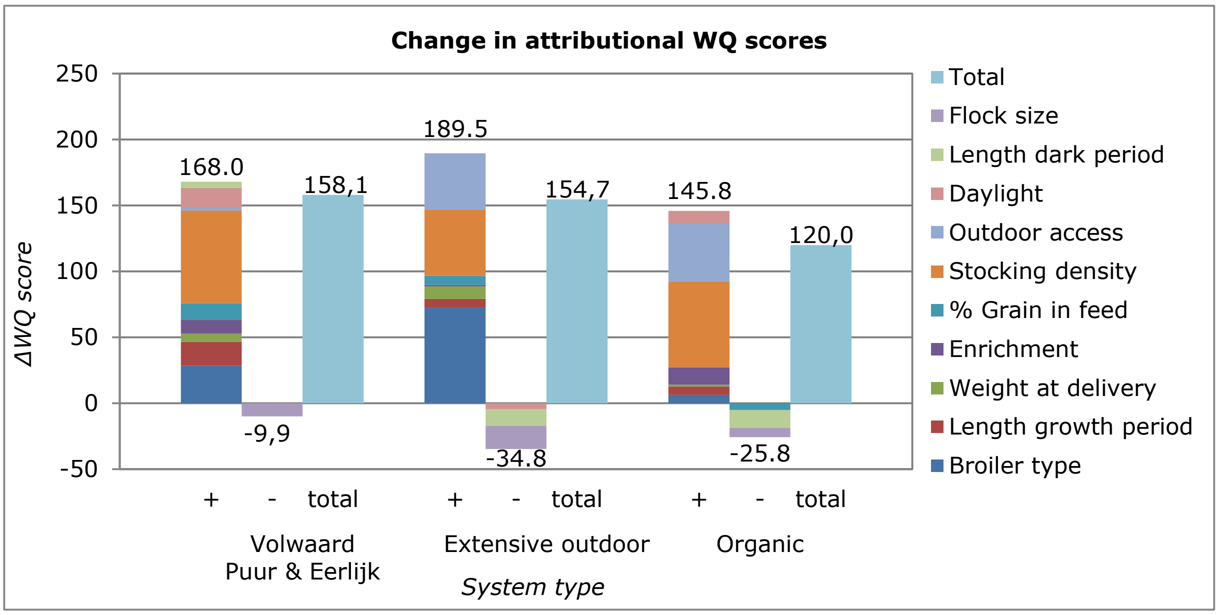

Figure 4. Change in attributional WQ scores compared to the conventional system

3.2 Costs results

For all system types, variable and fixed costs were determined. Table 7 and Figure 5 present the variable costs in Euros per delivered broiler for all system types.

Table 7. Variable costs (€/delivered broiler) per system type

	System type			
	Conventional	Volwaard Puur & Eerlijk	Extensive outdoor	Organic
Purchase chicken	0.32	0.34	0.34	0.47
Feed	0.97	1.21	1.29	2.83
Healthcare	0.05	0.04	0.04	0.04
Litter	0.01	0.03	0.03	0.33
Heating	0.05	0.07	0.07	0.09
Water	0.01	0.01	0.01	0.02
Electricity	0.02	0.02	0.02	0.01
Mortality	0.03	0.02	0.03	0.05
Delivery	0.04	0.04	0.04	0.04
General costs, manure disposal	0.03	0.03	0.03	0.01
Interest animals	0.01	0.01	0.01	0.02
Control fee organic	0.00	0.00	0.00	0.03
Total variable costs	1.52	1.81	1.90	3.92

Variable costs increased moving from the conventional system to the organic system. In all system types, the highest variable costs were feed costs. Costs for one-day-old chicks also were a main contributor. The purchase price for one-day-old chicks did not differ much between the conventional system on the one side and the Volwaard and Puur & Eerlijk systems and the extensive outdoor system on the other side. In the organic system, the purchase price of one-day-old chicks was considerably higher. Feed costs increased moving from the conventional system to the organic system, with the organic system showing very high feed costs compared to the other system types. Feed costs per delivered broiler were almost tripled in the organic system compared to the conventional system and more than doubled compared to the Volwaard and Puur & Eerlijk systems and the extensive outdoor system. High feed costs in the organic system were mainly due to legal requirements. Organic feed must be GMO-free and must contain at least 65% grains and at least 95% organic substances (Bokkers and de Boer, 2009; Ellen et al., 2012). Moreover, in the conventional system and the Volwaard and Puur & Eerlijk systems, € 0.035 per kg feed was subtracted from the feed costs to correct for bulk discount (Gocsik et al., 2013; KWIN-V, 2011-2012).

Healthcare costs were somewhat higher in the conventional system and equal in the other system types, because of the use of a fast growing breed (Gocsik et al., 2013; Van Horne et al., 2003). Litter costs were relatively low in the conventional system, the Volwaard and Puur & Eerlijk systems and the extensive outdoor system, while in the organic system, litter costs were relatively high. This was because of the provision of grain and straw. Heating costs increased moving from the conventional system to the organic system, with heating costs in the organic system being twice the heating costs in the conventional system. This was due to the covered veranda (in the Volwaard and Puur & Eerlijk systems) or outdoor run (in the extensive outdoor system and the organic system, Gocsik et al., 2013; Van Horne et al., 2003). Electricity costs were equal in all system types except the organic system. Electricity costs in the organic system were half the costs in the other system types. Mortality costs were highest in the organic system, followed by the conventional system. Delivery costs were almost equal in all system types. General costs included levies and costs of collecting cadavers. It also included manure disposal costs in all system types except the organic system. It was assumed that the demand for organic manure was high enough for manure removal costs to be equal to zero (Bokkers and de Boer, 2009; Gocsik et al., 2013). As a result, general costs were much lower in the organic system and equal in the other system types. Broiler interest costs increased moving from the conventional system to the organic system. Calculated interest was 6% on average invested capital in broilers (see Gocsik et al., 2013). Overall, total costs increased moving from the conventional system to the organic system, with a sharp increase for the latter one.

Figure 5 clearly shows that there were two cost items contributing most to total variable costs, namely feed costs and costs of purchasing chickens. To reflect the magnitude of these two cost items, costs were reflected as percentage of the total variable costs (Table 8). Moving from the conventional system to the organic system, the proportion feed costs increased. This coincided with the finding that when regarding feed costs in absolute values, feed costs were the main cause of the sharp increase in total variable costs in the organic system. Contrary to the proportion of feed costs, the proportion costs of purchasing one-day-old chicks decreased when moving from the conventional system to the organic system. Comparing feed and purchase chicken costs together, negligible differences existed between the system types.

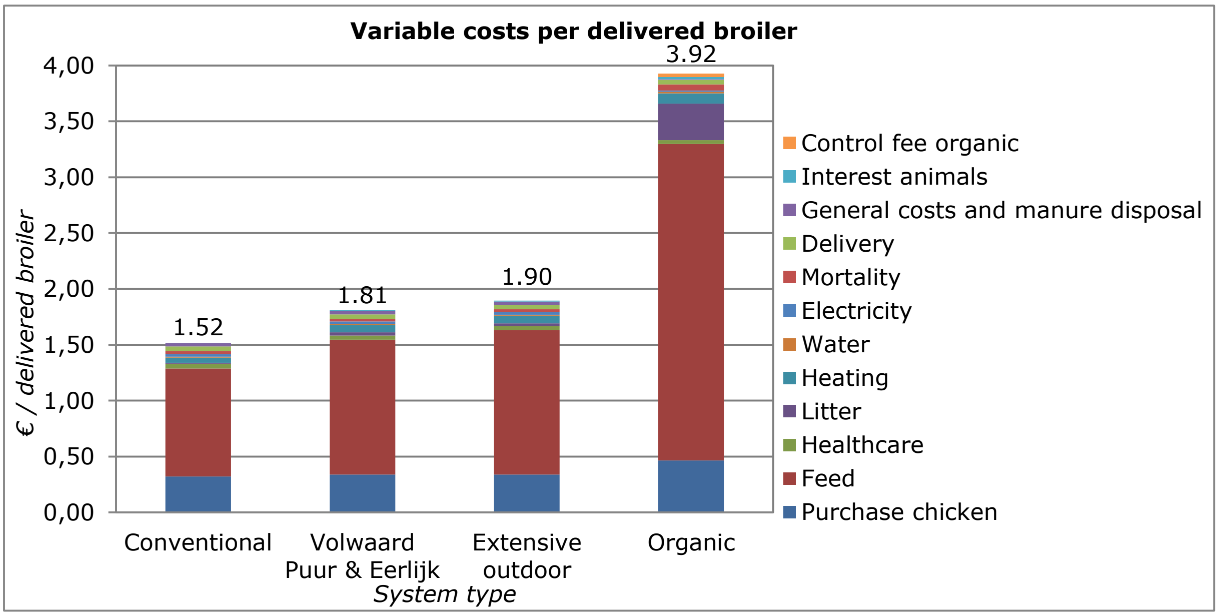

Figure 5. Variable costs (€/delivered broiler) per system type

Table 8. Feed costs and purchase chicken costs as percentages of total costs per system type

	System type			
	Conventional	Volwaard Puur & Eerlijk	Extensive outdoor	Organic
Purchase chicken	21%	19%	18%	12%
Feed	64%	67%	68%	72%
Total	85%	86%	86%	84%

Table 9 and Figure 6 show the fixed costs in Euros per delivered broiler in all system types. Fixed costs increased moving from the conventional system to the organic system. Labour costs showed a relatively high increase. This was due to an increase in labour requirements per delivered broiler because of additional activities, such as provision of grain or controlling outdoor access. As a result, roughly the same total amount of labour hours was needed in all system types, while less broilers can be kept when moving from the conventional to the organic system type (Table 4).

Fixed costs of buildings, inventory and land are visualized in detail in Figure 7. Fixed costs of buildings and inventory consisted of depreciation, interest and maintenance costs. For the extensive outdoor and the organic systems, interest costs of land were calculated. Depreciation and interest costs of buildings and inventory were main contributors, while maintenance costs of buildings and inventory were less important. Depreciation, interest and maintenance of investment costs of buildings and inventory all increased moving from the conventional system to the organic system. The interest benefit only held for organic investments. Increase in fixed costs of buildings, inventory and land in the Volwaard and Puur & Eerlijk systems and the extensive outdoor system compared to the conventional system were mainly due to an increase in depreciation and interest of investment costs of buildings and inventory. The same fixed costs contributed to the high increase in total costs in the organic system compared to the other system types. Additionally, the interest costs of land contributed considerably to the high fixed costs per delivered organic broiler.

Table 9. Fixed costs (€/delivered broiler) per system type

	System type			
	Conventional	Volwaard Puur & Eerlijk	Extensive outdoor	Organic
Own labour	0.09	0.16	0.23	0.53
Buildings, inventory and land	0.23	0.39	0.47	0.77
depreciation buildings	0.06	0.10	0.11	0.21
depreciation inventory	0.05	0.08	0.10	0.11
interest buildings and inventory	0.10	0.17	0.19	0.33
interest benefit (organic)	0.00	0.00	0.00	-0.07[1]
maintenance buildings	0.01	0.02	0.03	0.05
maintenance inventory	0.01	0.02	0.02	0.03
interest land	0.00	0.00	0.02	0.11
Total fixed costs	0.32	0.55	0.71	1.30

[1] the organic system benefits from a lower interest rate (so-called "green interest", Gocsik et al., 2013; Vermeij and van Horne, 2008), that was calculated using an interest benefit

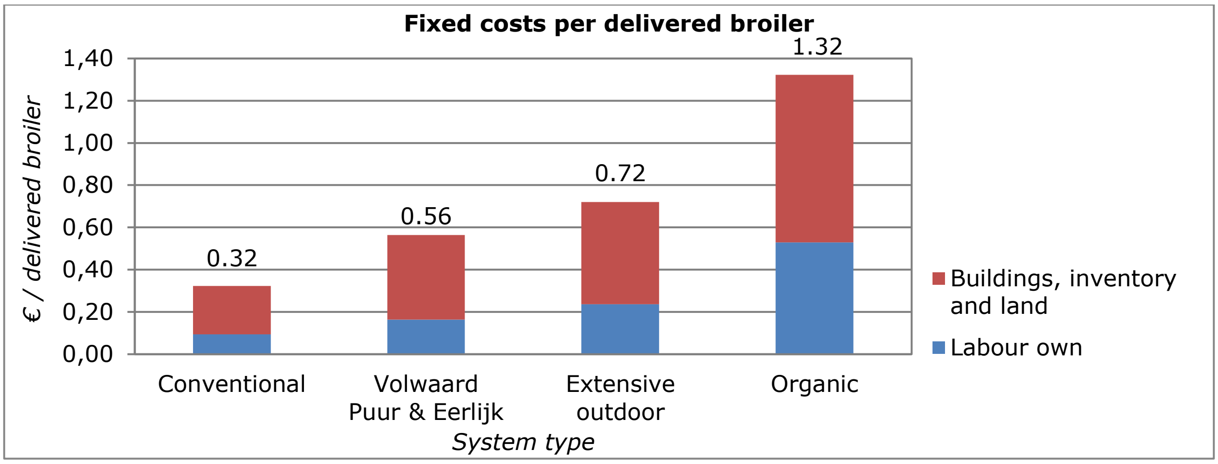

Figure 6. Fixed costs (€/delivered broiler) per system type

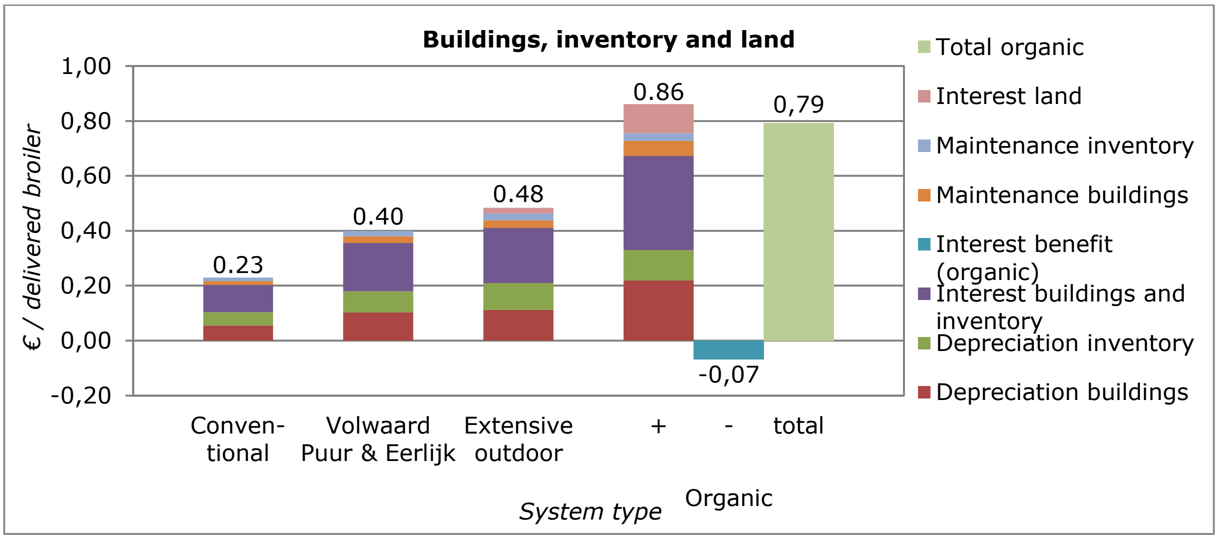

Figure 7. Fixed costs (€/delivered broiler) per system type: costs of buildings, inventory and land

Figure 8 presents the total costs per delivered broiler in all system types. Total costs were equal to € 1.84, € 2.37, € 2.62 and € 5.25 per delivered broiler in the conventional system, the Volwaard and Puur & Eerlijk systems, the extensive outdoor system and the organic system, respectively. Compared to the total costs in the conventional system, total costs in the Volwaard and Puur & Eerlijk systems were 1.3 times higher, total costs in the extensive outdoor system were 1.4 times higher, and total costs in the organic system were 2.9 times higher. Total costs in Euros per kg broiler meat were € 0.84, € 1.03, € 1.24 and € 2.01 in the conventional system, the Volwaard and Puur & Eerlijk systems, the extensive outdoor system and the organic system, respectively. When considering total costs per kg broiler meat, costs were 1.2 times higher in the Volwaard and Puur & Eerlijk systems, 1.5 times higher in the extensive outdoor system, and 2.4 times higher in the organic system, relative to the conventional system.

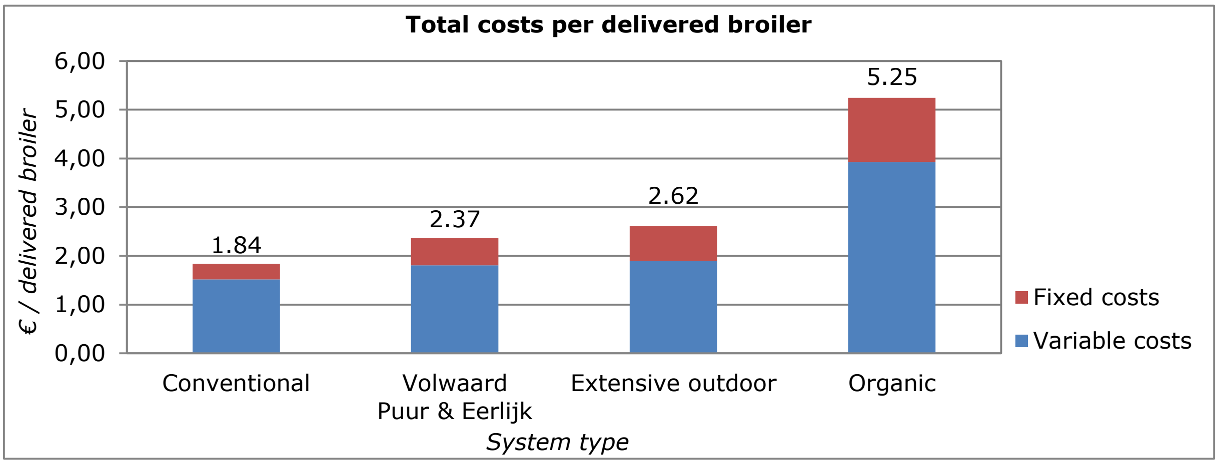

Figure 8. Total costs (€/delivered broiler) per system type

3.3 Analysis of WQ scores and costs

To obtain insight in the cost-efficiency of broiler welfare, total costs (TC) and WQ Index scores were analysed simultaneously. To enable such an analysis, the conventional system was used as reference and the alternative system types were compared to the conventional system. For this, both the difference in WQ Index score (ΔWQ Index) and the difference in total costs (ΔTC) were determined for each alternative system type relative to the conventional system (Figure 9). Additionally, Table 10 presents the marginality matrix showing the difference in WQ Index scores and in TC when moving from one system type (shown in the rows) to another (shown in the columns). It can be observed that when moving from the conventional system to the Volwaard and Puur & Eerlijk systems, the difference in WQ Index score was equal to 158, that was an increase of 27%. TC increased with € 0.19 (23%). In the extensive outdoor system, ΔWQ Index was equal to 155 (27%) and ΔTC was equal to € 0.41 (49%) relative to the conventional system. Comparing the organic system with the conventional system resulted in an increase in WQ Index of 120 (21%) and an increase in TC of € 1.18 (141%).

Next to the comparison with the conventional system, the Volwaard and Puur & Eerlijk systems and the extensive outdoor system were also set as reference in the matrix. Moving from the Volwaard and Puur & Eerlijk systems to the extensive outdoor system resulted in a slight decrease in WQ Index score equal to 3 and an increase in total costs of € 0.21 (21%). The decrease in WQ Index in the organic system compared to the Volwaard and Puur & Eerlijk systems was equal to 38, that was a decrease of 5%. Contrarily, total costs increased with € 0.98 (95%). The same percentage decrease was observed for the WQ Index score in the organic system compared to the extensive outdoor system (with an absolute decrease equal to 35). Total costs increased with € 0.77 (62%).

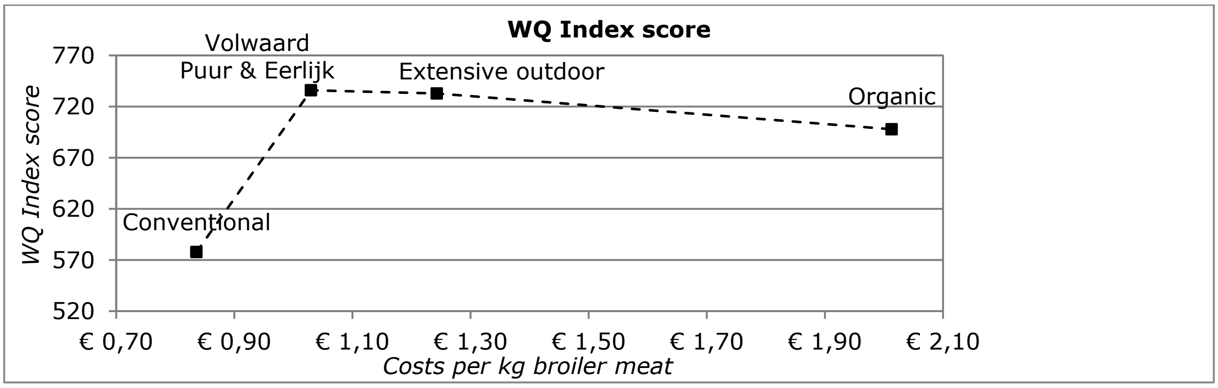

Figure 9. WQ Index scores plotted against total costs (€/kg meat) per system type

Table 10. Change in WQ Index score and change in total costs (€/kg meat) per system type

To	Volwaard Puur & Eerlijk		Extensive outdoor		Organic	
From	ΔWQ Index[1]	ΔTC[2]	ΔWQ Index	ΔTC	ΔWQ Index	ΔTC
Conventional	158 (27%)	€ 0.19 (23%)	155 (27%)	€ 0.41 (49%)	120 (21%)	€ 1.18 (141%)
Volwaard, Puur & Eerlijk			-3 (0%)	€ 0.21 (21%)	-38 (-5%)	€ 0.98 (95%)
Extensive outdoor					-35 (-5%)	€ 0.77 (62%)

[1] change in WQ Index score

[2] change in total costs

Overall, the highest gain in WQ Index score with the conventional system as reference was in the Volwaard and Puur & Eerlijk systems and the extensive outdoor system. The lowest increase in total costs was observed in the Volwaard and Puur & Eerlijk systems. Furthermore, comparing the organic system with the Volwaard and Puur & Eerlijk systems and the extensive outdoor system presented a decrease in WQ Index score of 5%, while total costs increased considerably.

3.4 Sensitivity analysis

Since no methodology existed yet to link system attributes to welfare measures and consequently an 'own' method had to be developed, the strength of the used methodology was not clear. Therefore, a sensitivity analysis was done on the WQ Index scores. Sensitivity was reflected by the standard error. Additionally, since prices can fluctuate considerably, a sensitivity analysis was done to analyse the effect of these fluctuations on total costs in Euros per kg broiler meat. For both one-day-old chick prices and feed prices of the conventional system, the minimum and maximum prices over a time-span of five years (2008-2012) were taken as extremes (KWIN-V, 2008-2012). Subsequently, since data was lacking for the alternative system types, the same price premiums were used for calculating minimum and maximum prices for the alternative system types as done before (see Table 4 for price premiums). Sensitivity was reflected using a worst-case scenario, at which maximum prices for both one-day-old chicks and feed were used and a best-case scenario, at which minimum prices for both one-day-old chicks and feed were used for calculating total costs. An overview of the results is given in Table 11 and Figure 10.

Table 11. Sensitivity analysis results on WQ Index scores and total costs (€/kg meat) per system type

	System type			
	Conventional	Volwaard Puur & Eerlijk	Extensive outdoor	Organic
WQ statistics				
WQ Index score (±SE)	578 (±6.4)	736 (±13.5)	733 (±24.0)	698 (±26.3)
WQ max	790	884	850	724
WQ min	381	602	624	672
Cost statistics				
Worst case (deviation from mean)	€ 0.97 (0.14)	€ 1.19 (0.16)	€ 1.41 (0.17)	€ 2.31 (0.30)
Best case (deviation from mean)	€ 0.76 (0.08)	€ 0.94 (0.09)	€ 1.15 (0.09)	€ 1.87 (0.14)

Standard errors in the conventional system, the Volwaard and Puur & Eerlijk systems, the extensive outdoor system and the organic system were equal to respectively 6.4, 13.5, 24.0 and 26.3. So, the standard error of the WQ Index score increased moving from the conventional system to the organic system. In the conventional system, total costs in Euros per kg broiler meat ranged from € 0.76 in the best case scenario to € 0.97 in the worst case scenario. In the Volwaard and Puur & Eerlijk systems, the extensive outdoor system and the organic system, ranges were equal to € 0.94 - € 1.19, € 1.15 - € 1.41 and € 1.87 - € 2.31 per kg broiler meat. These results show that when moving from the conventional system to the organic system, the amplitude and thus the sensitivity of the total costs increased. As can be observed in Figure 11, variation in WQ Index score was relatively small compared to the jump in WQ score between the conventional system and the Volwaard and Puur & Eerlijk systems. The same could be observed at total costs between the extensive outdoor system and the organic system. However, some overlap existed in the range of WQ Index score in all three alternative system types and in the range of total costs in the conventional system, the Volwaard and Puur & Eerlijk systems and the extensive outdoor system.

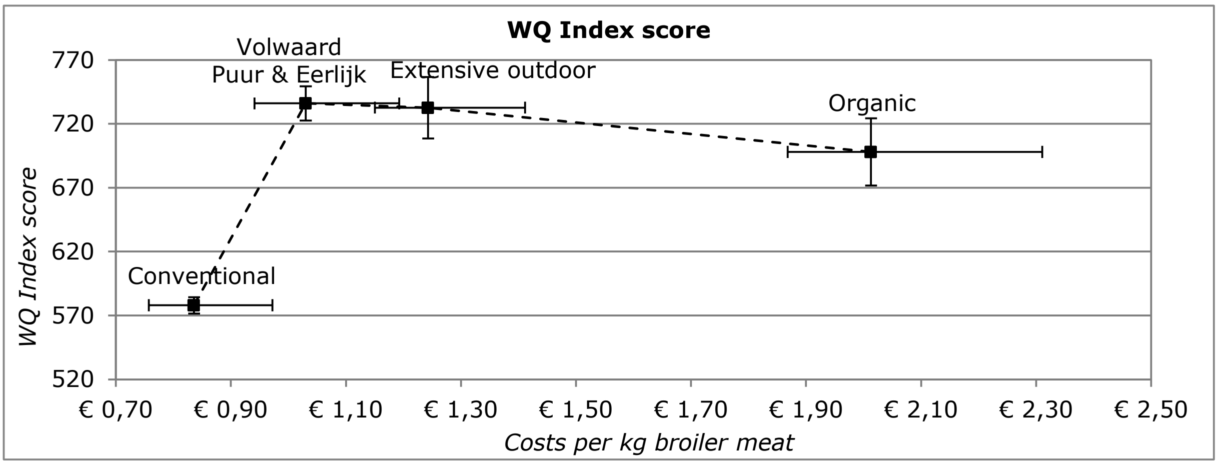

Figure 10. Sensitivity analysis results on WQ Index scores and total costs (€/kg meat) per system type

Since feed costs were very high in the organic system, a comparison of variable costs was made in the case the feed costs in Euros per kg feed would be equal in the organic system and the conventional system. Feed costs in the organic system were € 41.89 per 100 kg compared to € 29.50 per 100 kg in the conventional system. Feed costs per delivered broiler were calculated as follows:

*Feed costs (€/delivered broiler) = W * FCR * C_f* (4)

where W = weight at delivery (kg),
FCR = feed conversion ratio (kg feed/kg weight),
C_f = feed costs (€/kg).

For a comparison of variable costs in the case feed costs in Euros per kg feed would be equal in both system types, the feed price in Euros per kg of the conventional system was used to calculate feed costs in Euros per delivered broiler for the organic system. This system type was called 'organic system with feed correction'. Next to feed costs in Euros per delivered broiler, mortality costs and interest costs on average invested capital in broilers were affected. Table 12 shows values of these three cost items in the conventional system, the organic system and the organic system with feed correction. The three system types are visualised in Figure 11. While feed costs decreased considerably, mortality costs and interest costs decreased just slightly (from € 0.053 to € 0.041 and from € 0.022 to € 0.017, respectively). The latter two decreased since their values were dependent on feed costs (see Appendix I). Total variable costs of the organic system with feed correction were still roughly twice as high as total variable costs of the conventional system. The total variable costs of the organic system with feed correction were equal to € 3.07.

Table 12. Affected costs (€/delivered broiler) of conventional, organic and organic with feed correction

	System type		
	Conventional	Organic	Organic with feed correction
Feed	0.97	2.83	1.99
Mortality	0.03	0.05	0.04
Interest animals	0.01	0.02	0.02

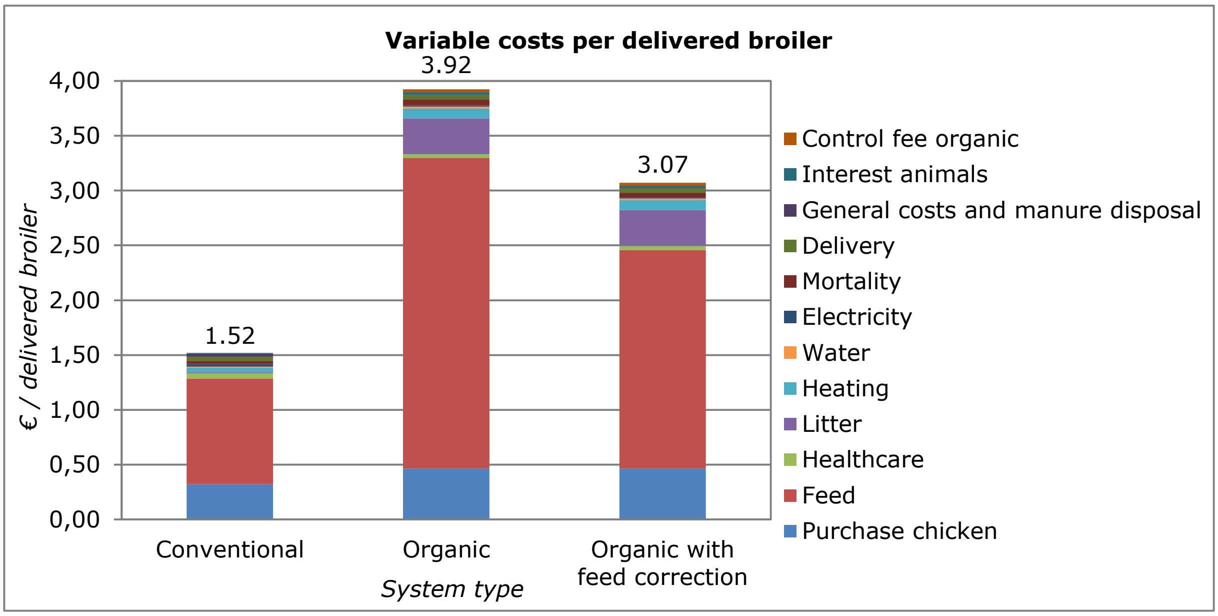

Figure 11. Variable costs (€/delivered broiler) of conventional, organic and organic with feed correction

Because of the used systematic, system types without outdoor access (the conventional system and the Volwaard and Puur & Eerlijk systems) received a WQ score on the system attribute outdoor access. This was due to the linking of several welfare measures to this system attribute that did obtain a welfare score in the system types without outdoor access. The linked welfare measures were plumage cleanliness, FPD, on farm mortality and free range. The system types did receive a welfare score equal to zero on the welfare measure free range, but at the other three welfare measures, a welfare score higher than zero was obtained. Because of this conflict, two ways to correct for the WQ score obtained at the system attribute outdoor access were analysed.

First, the obtained WQ scores on the system attribute outdoor access were changed to a value of zero in the system types without outdoor access (Table 13 and Figure 12). The corrected WQ Index scores were equal to 538 and 694 in the conventional system and the Volwaard and Puur & Eerlijk systems, respectively. This correction led to a decrease in WQ Index score of 40 (7%) in the conventional system and 42 (6%) in the Volwaard and Puur & Eerlijk systems compared to the original WQ Index scores. This was because weights did not add up to one for the concerning welfare measures in these system types anymore (and thus the correction resulted in a WQ Index score that was lower than the actual WQ Index score).

Table 13. Original and corrected WQ Index scores per system type

	System type			
	Conventional	Volwaard Puur & Eerlijk	Extensive outdoor	Organic
WQ Index score	578	736	733	698
Corrected WQ Index score	538	694	-	-

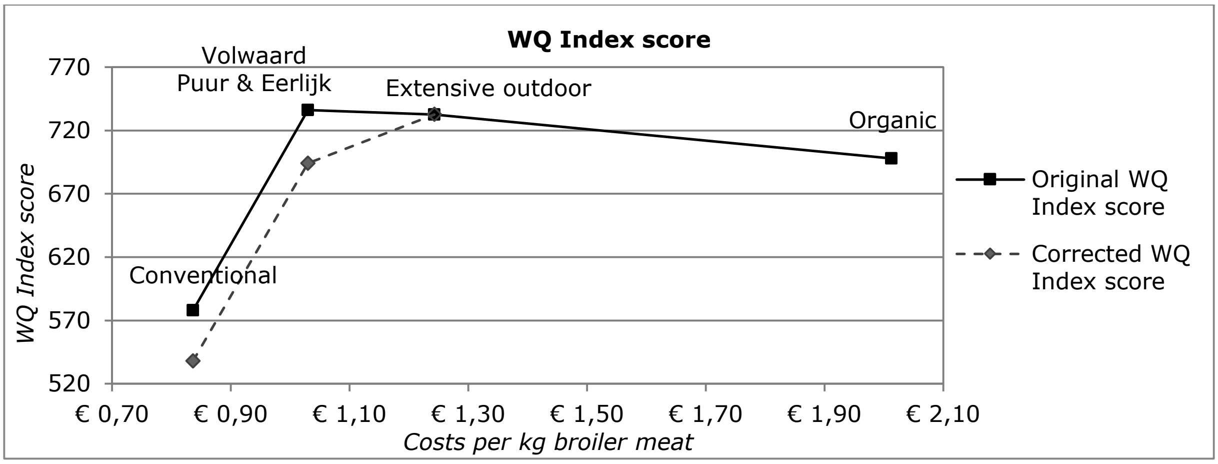

Figure 12. Original and corrected WQ Index scores plotted against total costs per system type

In Figure 12, the solid line shows the original WQ Index scores (without correction for outdoor access). The dashed line shows the corrected WQ Index scores of the system types without outdoor access. The corrected line more resembled a concave trend, with high increase in WQ Index score close to the origin and slight increase at the right side. In this situation, the WQ Index score of the extensive outdoor system was higher than the WQ Index score of the Volwaard and Puur & Eerlijk systems. The WQ Index scores of the organic system and the Volwaard and Puur & Eerlijk systems were almost equal.

Second, the WQ score of the system attribute outdoor access equal to zero in the system types without outdoor access was compensated by changing weights of other system attributes (Table 14). In other words, the linkages between the concerning welfare measures and other system attributes received a higher weight in the system types without outdoor access than they did in system types with outdoor access. This solved the problem of the weights not adding up to one and the resulting decreased WQ Index scores, but hindered comparison of the WQ scores of the concerning system attributes between system types with and without outdoor access. The system attributes that were affected by changing weights were broiler type, the percentage of grain in the feed, stocking density and length of the dark period. The corresponding attributional WQ scores were all somewhat increased, due to the larger weight given to the linkages.

Overall, the used methodology did not provide an appropriate solution. However, the analysis on outdoor access did not present highly different outcomes and therefore the same conclusions would hold for the results and for the situation in which a correction would have been made for outdoor access. The one exception was that the WQ Index score of the extensive outdoor system was higher than the WQ Index score of the Volwaard and Puur & Eerlijk systems.

Table 14. Original and corrected attributional WQ scores

	System type					
	Conventional		Volwaard Puur & Eerlijk		Extensive outdoor	Organic
	O[1]	C[2]	O	C		
Broiler type	193.79	206.44	222.19	238.28	266.32	200.13
% Grain in feed	6.49	8.66	18.91	25.22	13.11	1.33
Stocking density	103.23	115.82	173.75	177.26	153.51	168.46
Length dark period	137.55	150.20	142.10	158.19	124.71	124.11

[1] original attributional WQ score
[2] corrected attributional WQ score

4 Discussion

Currently little is known about animal welfare improvement and additional costs of production system types compared to the conventional system, and the relation between both on system level. Additionally, little research has been done on the magnitude of impact of a specific system attribute on a welfare measure. Within this context, the thesis was implemented to gain insight in the level of animal welfare in several Dutch broiler production system types and in costs of these system types.

The aim was to evaluate several Dutch broiler production system types in terms of animal welfare (AW) and costs. For this, system attributes that influence AW had to be linked to welfare measures in the Welfare Quality® Assessment protocol for poultry (Welfare Quality®, 2009, further called "protocol"). This was a crucial step in the research to enable analysis of AW on system level.

The results show detailed figures on AW and variable and fixed costs in all four broiler production system types. The most important system attributes regarding AW could be pointed out and the cost items contributing most to total costs were defined. Moreover, differences in AW and costs were obtained between the different broiler production system types.

This Chapter describes the interpretation of the results, followed by a consideration of the methodology of linking system attributes to welfare measures and weighing. Additionally, the robustness of the results is discussed based on the findings at the sensitivity analysis. The Chapter ends with remarks on the implications for AW concept development and recommendations for future research.

4.1 Results

The results showed a difference in AW between the four broiler production system types. Compared to the conventional system, the Volwaard and Puur & Eerlijk systems obtained a considerably higher Welfare Quality (WQ) Index score. WQ Index scores of the extensive outdoor system and the organic system were also higher than the WQ Index score of the conventional system. However, the difference between the Volwaard and Puur & Eerlijk systems, the extensive outdoor system and the organic system was less obvious. The main contributors to AW for all system types were broiler type, stocking density and length of the dark period. The system attribute outdoor access was a main contributor especially for the system types with outdoor access.

Regarding total costs, large differences could be found between broiler production system types too. For both variable and fixed costs an increase was observed when moving from the conventional system to the organic system. In all system types, the highest variable costs were feed costs. Additionally, costs for one-day-old chicks were a main contributor. With respect to fixed costs, labour costs were main contributor. Depreciation and interest for investment costs of buildings and inventory also contributed considerably. Moreover, the analysis on reducing feed costs in the organic system showed that variable costs could be decreased considerably if the organic feed price would more resemble the conventional feed price.

The simultaneous analysis of WQ Index scores and total costs showed decreasing marginal returns in AW. The highest gain in WQ Index score with the conventional system as reference was in the Volwaard and Puur & Eerlijk systems and the extensive outdoor system. Increase in total costs was lowest in the Volwaard and Puur & Eerlijk systems. Furthermore, comparing the organic system with the Volwaard and Puur & Eerlijk systems and the extensive outdoor system presented a decrease in WQ Index score of 5%, while total costs increased considerably between the extensive outdoor system and the organic system.

4.2 Method of linking system attributes to welfare measures and weighing

It was decided to link the system attributes to the individual welfare measures instead of the criteria in the protocol. This was because not all welfare measures that are used for a specific criterion could be linked to a specific system attribute. As a result, the formulas used in the protocol could not be applied, since they are criterion-based. Welfare scores obtained at the different welfare measures had to be transformed in WQ scores using allocation formulas. For this, all linkages were evaluated on their relative importance and obtained corresponding weights.

The linking of system attributes to welfare measures instead of welfare criteria was in line with the finding that in some cases the listing of welfare measures under specific criteria seemed doubtful. For example, plumage cleanliness is categorized under the criterion comfort around resting. However, since dirty plumage reduces isolation, it might as well be listed under thermal comfort. The main advantage of using the criteria is that they give a clear overview on the specific welfare aspect that is addressed. Nevertheless, since several welfare measures may be categorized under multiple criteria, it is better to base conclusions on the welfare measures, so that it is sure that the right welfare aspect is addressed. Another aspect that needs to be noted is that it is stated in the protocol that welfare measures are unrelated. However, some welfare measures were found to relate to each other, e.g. litter quality, lameness, hock burn and foot pad dermatitis. In other words, interaction does exist between different welfare measures. However, since information on the interactions between welfare measures is lacking, an additive model was used.

The linking of system attributes to welfare measures and thus the associated weighing has never been done before. Because of this, no method was readily available and an 'own' method had to be developed. The method was based on an extensive literature review on relations between system attributes and welfare measures and based on expert opinion. Since little research has been done on the magnitude of impact of a specific system attribute on a welfare measure, the weighing was somewhat arbitrary. Weighing was done based on own interpretation of the literature and in consultation with dr.ir. I. de Jong.

It has to be noted that the thesis concerns a pilot study. More research is needed on the relation between system attributes and AW within the different broiler production system types so that a well-founded methodology can be developed.

4.3 Robustness of the results

Because of the uncertainty on the strength of the used method, an extensive sensitivity analysis was performed, at which both variability in WQ Index scores and in total costs were analysed. Sensitivity of both the WQ Index score and total costs increased moving from the conventional system to the organic system. Overall, the results were found to be robust. Regarding WQ Index score, this especially held between the conventional system and the Volwaard and Puur & Eerlijk systems. Sensitivity in WQ Index score did not bridge the jump in WQ Index score. The same was observed for total costs between the extensive outdoor system and the organic system. However, some overlap existed in the range of WQ Index score of all three alternative system types and in the range of total costs of the conventional system, the Volwaard and Puur & Eerlijk systems and the extensive outdoor system. Overall the results became less robust when moving beyond the Volwaard and Puur & Eerlijk systems. This is in line with the small sample sizes of the extensive outdoor system and the organic system.

The analysis on the WQ Index score when correcting for outdoor access in the broiler production system types without outdoor access did not result in large differences compared to the initial situation and therefore did not influence conclusions considerably. The only difference in conclusion is that the extensive outdoor system and the organic system performed better regarding WQ Index score than the Volwaard and Puur & Eerlijk systems.

4.4 Implications for AW concept development

The results show that large gains in AW can be made at relatively low costs. Marginal returns in AW decreased moving from the conventional system to the organic system, and cost-efficiency of AW was highest when moving from the conventional system to the Volwaard and Puur & Eerlijk systems. Moving beyond the Volwaard and Puur & Eerlijk systems presented lower cost-efficiencies. However, these results were also shown to be less robust.

Overall, it seems that the largest gains in AW are made in the middle segment. Beyond this segment, little or even no additional improvement of AW occurs. At this point, other aspects than AW become important that make up for the increase in total costs, like the wish to keep animals outside or other personal beliefs of the farmer. The majority of Dutch broiler farmers still produces conventional broiler meat (Ellen et al., 2012), and even if farmers shift to an alternative system with improved AW, they are most likely to shift to the middle segment. Two main reasons for this are the lower investment costs compared to shifting from conventional production to the extensive outdoor system or the organic system and the lower level of risk involved. Next to farmers, other main actors that influence the adoption of alternative broiler production systems are retailers and consumers. Since farmers (fully) rely on retailers with respect to sales, the preferences of retailers are as important as the wishes of the farmers themselves. Eventually, the attractiveness of adopting alternative broiler production systems depends on the consumer. Broiler production system types beyond the middle segment produce for a niche market, since the aspects are in line with the beliefs of a small group of consumers.

Future concept development should therefore focus on improving AW while integrating the ease of adoption for the farmers in relation to the wishes of a relatively large consumer group. Moreover, focus should lie on broiler type, stocking density and length of the dark period, since these system attributes were contributing most to AW. These two aspects seem to be in line with current development of new concepts within the middle segment. An example is the "Kip van Morgen", that is a new concept that with respect to AW lies between the conventional system and the Volwaard system. Focus lies on a slow growing breed that is kept a few days longer than in the conventional system and at a lower stocking density. The exact effect of this concept on AW is unknown, but it is expected that the level of AW is close to the level in the Volwaard system. What is really promising of this concept is that the extra costs involved are relatively low. No great adaptations are needed on the farm, that not only reduces additional costs but also severely reduces risk compared to other boiler production system types like the organic system. While adoption of, for example, the organic system is irreversible, moving from conventional production to a concept like the "Kip van Morgen" is reversible. This is a great advantage when the market does not reach expectations and therefore reduces risk.

4.5 Future research

Future research should focus on the middle segment. Moreover, more research needs to be done on the interaction between the AW influencing system attributes and between welfare measures. By this, a sound methodology for linking and weighing can be developed, so that an estimation of *true* levels of AW in the different broiler production system levels can be made. Furthermore, when taking interactions between system attributes into consideration, synergy between these attributes can be created so that in future broiler production systems as a whole AW can be increased even further.

Since multiple other broiler production system types exist next to the included broiler production system types in this thesis, research on these system types will result in a more clear overview on the cost-effectiveness of AW in the (Dutch) broiler production chain. Moreover, such research will gain insight on the middle segment more explicitly. Moreover, analysing costs and revenues simultaneously will provide insight into margins and viability of the different system types.

5 Conclusion

The contribution of the system attributes to the attributional Welfare Quality (WQ) scores of the different broiler production system types is complex. Many different trends were observed between both the welfare measures and the system attributes regarding welfare scores and attributional WQ scores, respectively. Overall, the highest gain in animal welfare (AW) with the conventional system as reference was in the Volwaard and Puur & Eerlijk systems and the extensive outdoor system. The WQ Index score of the organic system was also higher than the WQ Index score of the conventional system. However, the difference between the Volwaard and Puur & Eerlijk systems, the extensive outdoor system and the organic system was less obvious, and the WQ Index scores of the latter two were lower than the WQ Index score of the Volwaard and Puur & Eerlijk systems. The system attributes contributing most to AW were broiler type, stocking density and length of the dark period. The lowest increase in total costs was observed between the conventional system and the Volwaard and Puur & Eerlijk systems. Both variable and fixed costs increased moving from the conventional system to the organic system. Results were found to be relatively robust, as followed from the sensitivity analysis on the WQ Index scores and on total costs. Additionally, the effects of correction options on outdoor access on the conclusion were relatively low. Where originally the Volwaard and Puur & Eerlijk systems obtained the highest WQ Index score, the extensive outdoor system obtained the highest WQ Index score in this situation. The WQ Index scores of the organic system and the Volwaard and Puur & Eerlijk systems were almost equal.

Overall, it could be concluded that most can be gained when shifting from conventional broiler production to the middle segment. Within the middle segment, little difference in broiler welfare was found. Contrarily, a fairly large difference in total costs in Euros per kg broiler meat was observed. Moving beyond and within the middle segment does not significantly change broiler welfare, while total costs do increase considerably. Here, other personal values next to animal welfare also make up for the high costs. Focus on the middle segment while at the same time developing concepts that meet the needs of a large consumer group can maintain the “license to produce”, thereby enhancing the viability of the Dutch broiler sector.

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Appendix I. Overview of variable and fixed cost formulas

Variable costs

*Feed costs (€/delivered broiler) = W * FCR * C_f* (4)

where W = weight at delivery (kg)
FCR = feed conversion ratio (kg feed/kg weight)
C_f = feed costs (€/kg)

Costs of provision of grain and straw (€/delivered broiler) = $D_g * C_g + C_s$ (5)

where D_g = days to provide grain (d/round)
C_g = costs of grains (€/broiler/day)
C_s = costs of straw (€/broiler)

Mortality costs (€/delivered broiler) = $(C_{odo} + 0.5 * F) * m$ (6)

where C_{odo} = cost-price of one-day-old chicks (€/delivered broiler)
F = feed costs (€/delivered broiler)
m = mortality rate (%)

Delivery costs (€/delivered broiler) = C_c / N (7)

where C_c = catching costs (€/yr)
N = number of delivered broilers (#/yr)

Interest animals = $(C_{odo} + 0.5 * F) * i_L * L / 365$ (8)

where i_L = interest rate livestock (%)
L = length of the growth period (d)

Costs control fee organic = € 654,- / P (9)

where P = number of animal places

Fixed cost

Labour costs (€/delivered broiler) = $H * C_L / (P * r * (1 – m))$ (10)

where H = total working hours (hr/yr)
C_L = costs for own labour (€/hr)
r = rounds (#/yr)

Depreciation buildings (€/delivered broiler) = $(D_b + D_{b,aw}) / N$ (11)

where D_b = depreciation on investments in buildings (€)
$D_{b,aw}$ = depreciation on extra investments in AW in buildings (€)

Depreciation inventory (€/delivered broiler) = $(D_i + D_{i,aw} + D_f) / N$ (12)

where D_i = depreciation on investments in inventory (€)
$D_{i,aw}$ = depreciation on extra investments in AW in inventory (€)
D_f = depreciation on extra investments in fencing and outdoor facilities (€)

$$Interest = ((B_b + B_{b,aw} + B_i + B_{i,aw} + B_f) * i) / N \quad (13)$$

where B_b = book value investments in buildings (€)
$B_{b,aw}$ = book value extra investments in AW in buildings (€)
B_i = book value investments in inventory (€)
$B_{i,aw}$ = book value extra investments in AW in inventory (€)
B_f = book value on extra investments in fencing and outdoor facilities (€)
i = interest rate (%)

$$Maintenance\ buildings = ((R_b + R_{b,aw}) * m_b) / N \quad (14)$$

where R_b = replacement value investments in buildings (€)
$R_{b,aw}$ = replacement value extra investments in AW in buildings (€)
m_b = maintenance buildings (%)

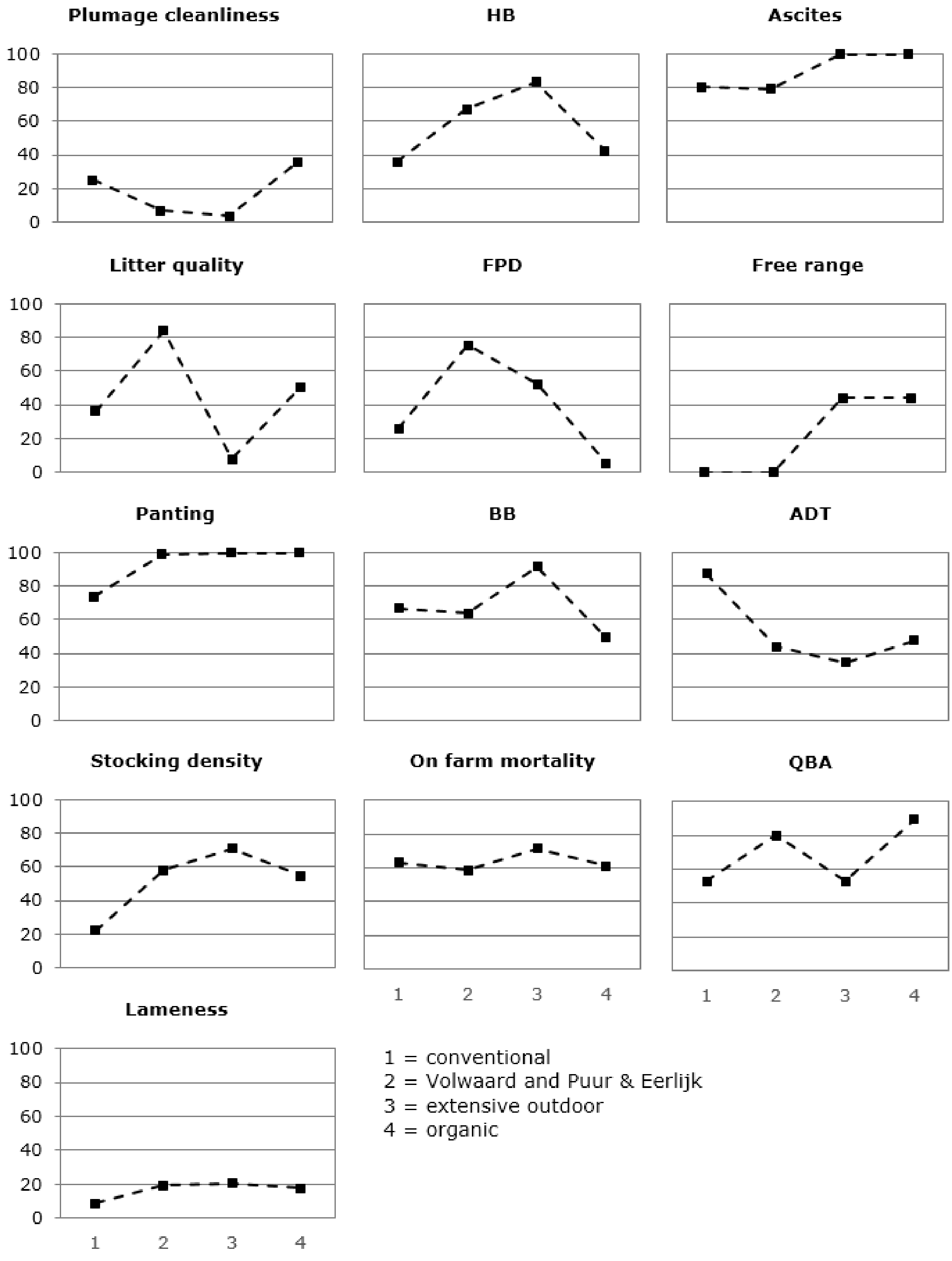
$$Maintenance\ inventory = ((R_i + R_{i,aw} + R_f) * m_i) / N \quad (15)$$

where R_i = replacement value investments in inventory (€)
$R_{i,aw}$ = replacement value extra investments in AW in inventory (€)
R_f = replacement value extra investments in fencing and outdoor facilities (€)
m_i = maintenance inventory (%)

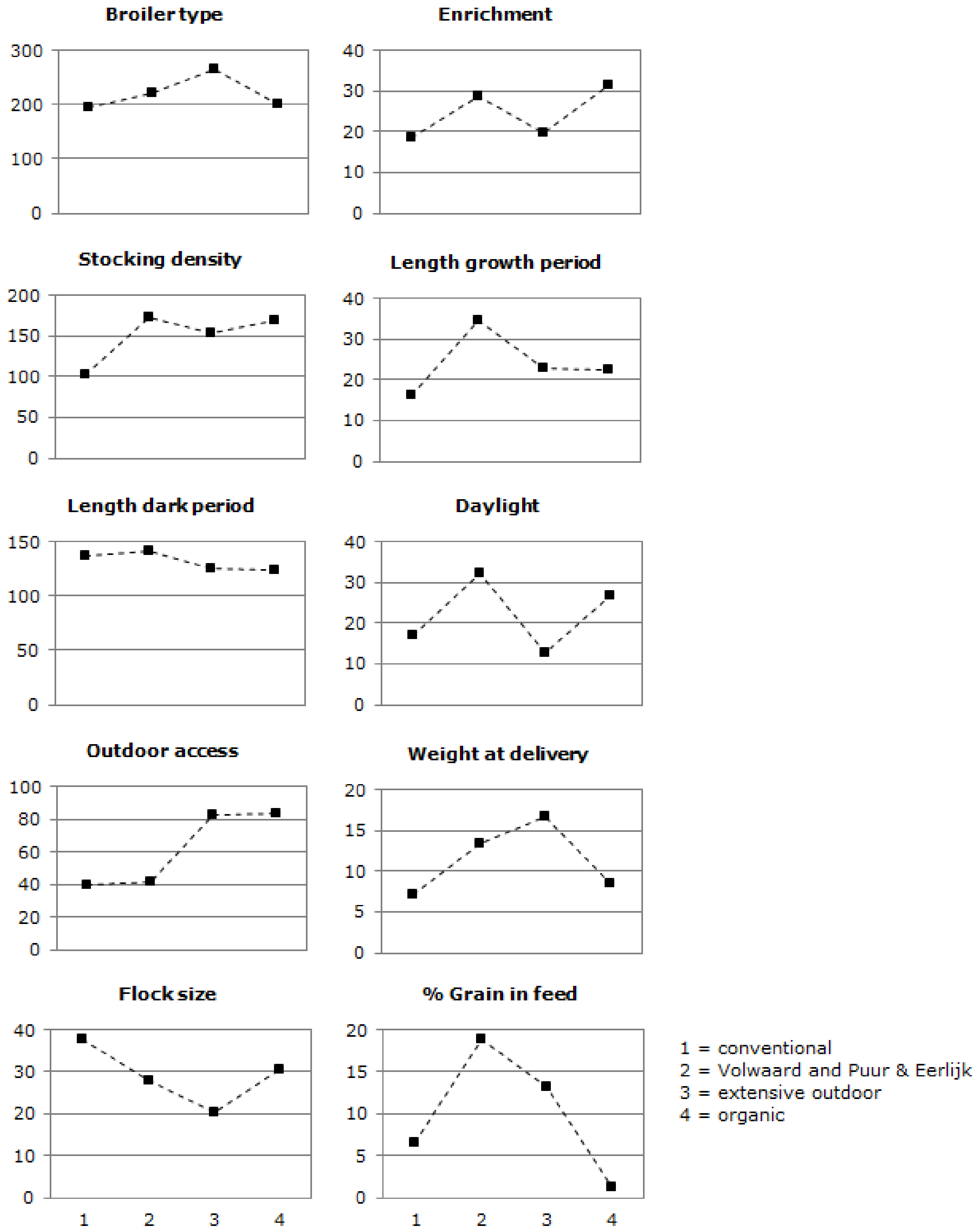
$$Interest\ land = (R_L * 0.5 * i) / N \quad (16)$$

where R_L = replacement value land (€)

Appendix II. Mean welfare scores on the welfare measures for all system types



Appendix III. Mean attributional WQ scores on the system attributes for all system types



Note the different scales on the y-axes.