Ph.D. Dissertation of Hyejin Kang

Welfare quality assessment for South Korean growing pig farms in winter using animal- and environment-based parameters

동물 및 환경 기반 변수를 이용한 겨울철 국내 육성돈 농장의 복지 수준 평가

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Abstract

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The objectives of this study were to evaluate the welfare quality of growing pigs in Republic of Korea (South Korea) using animal- and environment-based parameters, and reveal the correlation between the two parameters. In addition, the strengths and weaknesses of the welfare status of growing pigs in South Korea were identified by comparing the Welfare Quality® assessment results with those in European nations and South Korea using animal-based parameters. The results of this study can prove foundational in improving the welfare of pig farming in the future.

This study assessed nine conventional pig farms for the welfare quality assessment in South Korea using animal-based (Welfare Quality® protocol) and environment-based parameters (particularly air quality parameters) during the winter of 2013. The Welfare Quality® protocol, an animal-based parameter, comprises of 12 criteria within four principles, “good feeding,” “good housing,” “good health,” and “appropriate behaviors”, each of which was assessed using one or several measures. Four criteria were combined into an overall assessment to indicate the welfare level of pig

farms. The Welfare Quality® protocol classifies farms into four categories ranging from “excellent” to “not classified (below acceptable).” The overall assessments found five out of nine farms to be “acceptable,” four to be “enhanced”, and not a single farm to be “not classified.” The principles considering the average score across the nine farms are arranged in a decreasing order as follows: “good feeding” > “good housing” > “good health” > “appropriate behaviors." Serious animal welfare problems related to the following criteria: 1) “absence of pain induced by management procedures” and 2) “positive emotional state” and “expression of other behaviors.”

Environment-based parameters include the microclimate (temperature, relative humidity, air speed, particulate matter (PM)), airborne bacteria (total airborne bacteria, airborne total coliform, airborne total *e. coli*), concentration of gases (carbon dioxide, ammonia, hydrogen sulfide). The ammonia concentrations and the relative humidity in four out of nine farms were higher than the threshold limit values.

The correlation between animal- and environment-based parameters concluded that animal welfare, particularly the criterion “positive emotional states,” can be improved by controlling air quality, such as ammonia, hydrogen sulfide, and carbon dioxide, in the correlation between welfare assessment results using both parameters.

The European nations and South Korea showed different patterns in the results of the Welfare Quality® protocol on growing pigs. In principle, “good feeding” and “good housing” in South Korea were similar to those of the European nations, but “good health” and “appropriate behaviors” were

worse. The low score with the principles in South Korea is mainly due to the low scores of the criteria “absence of pain induced by management procedures,” “expression of other behaviors,” and “positive emotional state.” Studying the systems and procedures related to the welfare improvement of farm animals in Europe is necessary to enhance the welfare status in these criteria, expand the related research in South Korea, and promote efficient system improvement, such as expanding incentives for animal welfare farms, to realize their application to the South Korean situation.

Keyword: animal welfare, Welfare Quality® protocol, animal-based parameters, environment-based parameters, multi-criteria evaluation, air quality parameters, comparison with the European nations

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List of Abbreviation

A	Acceptable
AA	average ages
AB	appropriate behaviors
AC	airborne total coliform
AD	absence of disease
AE	airborne total *e. coli*
AI	absence of injuries
ANI	Animal Needs Index
APH	absence of prolonged hunger
APMP	absence of pain induced by management procedures
APT	absence of prolonged thirst
AS	air speed
AVE	average
AW	average weight(kg)
B	Breeder
BT	breeding type
CAR	comfort around resting
CO_2	carbon dioxide
DFD	dark, firm and, dry
E	enhanced
EM	ease of movement
EOB	expression of other behaviors
ESB	expression of social behavioiurs
EU	European Union
F	Fattener
GF	good feed

GH	good housing
GHE	good health
GHR	good human relationship
H_2S	hydrogen sulfide
HAR	human-animal relationship
HPA	Hypothalamic-Pituitary-Adrenal
NGO	Non-governmental organization
NH_3	Ammonia
NPF	number of pigs in the farm
NPP	number of pigs per pen
PES	positive emotional state
PM	particulate matter
PSE	pale, soft, and exudative
QBA	qualitative behavioral assessment
RH	relative humidity
SAK	space allowance/100kg
SAP	space allowance/pig
SD	standard deviation
TAB	total airborne bacteria count
TC	thermal comfort
TEM	temperature
TGI	Tiergerechtheitsindex
TSP	total suspended particulate matter

Chapter 1. Introduction

1.1. Definition of animal welfare

1.1.1. Three main concept to define animal welfare

Welfare comprises physical and mental health (1) and includes various aspects such as absence of hunger, thirst, discomfort, disease, pain, injury, stress, and the expression of normal behavior (2). Most study on animal welfare has focused on preventing animal suffering over the past 4 decades, but now societal interest in providing positive emotional experiences for farm animals is increasing (3,4,5,6). Since each animal has a different way of coping with stressors (9,10), the use of multiple indicators from multiple disciplines should be required to understand and evaluate animal welfare (5,7,8).

There are three main concept to define animal welfare. The first approach emphasizes the well-being of animals based on the presence of adequate biological functioning, such as growth and reproductive performance, as well as health status and behavioral characteristics (9,11). The welfare of an Individual is its state as regards its attempts to copy with its environment (9). To cope with challenges, animals activate the functions of body recovery systems, immunological defenses, physiological stress responses, and several behavioral responses. These reactions can ultimately affect animal growth, health, and reproduction. Serious stress can limit an animal's ability to copy and as such lead to its death. This stress can be directly measured and interpreted as providing information on animal welfare (12).

A second approach assess that welfare is all about the animal's emotional state and whether it is suffering, i.e., "*welfare is dependent on what animals feel*" (13). Concerns about animal welfare are generally based on the assumption that animals can experience emotional states subjectively, such as pain or pleasure (14,15,16). Animal suffering is very difficult to deal with, but it is the center of the concept of animal welfare for many scientists and is probably the most important factor when the public forms opinions on farm animal welfare (17).

Thirdly, there is the concept that welfare is to do with the extent to which an animal can behave naturally - i.e., "*in order to avoid suffering, it is necessary over a period of time for the animal to perform all the behaviors in its repertoire because it is all functional*" (18). Normal behavioral patterns are usually related to the behavior shown by most members of the species under natural conditions. These behaviors can be compared to those shown by animals under more limited conditions and can be used as welfare assessment because they provide the basis for animal's requirements (19). However, since domestic species have genetically adapted to their new niches living among humanity (20), the definition of whether they are normal or even harmful to animals living in various residential environments is not simple (19).

1.2. Measurement of Animal welfare

Animal welfare is multidimensional so that it cannot be measured directly by a single measure (7) but rather requires a great variety of

parameters for the overall welfare assessment. In general, these parameters can be divided into two main categories: environment-based and animal-based.

1.2.1. Environment-based parameters

The environment-based parameters evaluate the resource- and management-based parameters in the animal houses. In fact, much legislation is based on environment-based parameters such as the space allowance, type of floor, quality of litter, feeding and drinking facilities etc. It assumes a direct relationship between environmental aspects and the actual welfare state of animals and is an excellent basis providing advice on the prevention of welfare problems and the detection of risks to poor welfare (19,21). Assessment is also simple as environment-based parameters are relatively easy and quick, and the recordings can usually be repeated without difficulty. Questionnaires on management-based parameters such as feeding or procedures such as castration, tail-docking, ear tagging etc. may also be very useful in practice (19). According to Whay et al. (22), for dairy cattle the environmental assessment included a general assessment of housing conditions, features of cubicles, cleanliness of the environment, feeding trough space and calf pens. For pigs the environment parameters included assessment of barren conditions/foraging opportunities, water and food facilities, bedding (cleanliness and thermal comfort), housing space allowance, lighting, ventilation, absence of sharp edges and availability of group housing. The most relevant environment-based parameters for laying

hen are general assessment of housing conditions, feed and water facilities, ammonia levels, litter quality, nest box provision, perch length and general resources.

1.2.2. Animal-based parameters

The second category of measurement is animal-based parameters that records the state of animals by observing the animal more directly. This assessment measurement was developed from the idea that the provision of good environment does not necessarily guarantee a high standard of welfare for the animals (23). Since the welfare status of animals depends on how well they can survive and remain fit within the environmental conditions in which they live, animal-based parameters represent the welfare status of animals more directly (24). Animal-based parameters are generally considered more valid welfare assessment parameters compared to environment-based parameters (19). However, the recording of some of these parameters is difficult, not to mention the considerably larger amounts of resources and time it takes. In recent years, the assessment of animal welfare has moved from the conventional approach of evaluating the environment, to animal-based parameters (25). Animal-based parameters fall into four main categories: performance, health, physiology, and behavior.

1.2.2.1. Performance

When attempts to cope with challenging situations are accumulated, it will ultimately affect the animal and their performance. Thus, continuous

records of performance can provide the general information on the welfare status of farm animals (19). Feed intake and growth rate of growing pigs (26) are performance parameters that can detect welfare problem. Meat quality also can be indicators of acute stress or chronic stress. The prevalence of PSE (Pale, soft, and exudative) and DFD (Dark, firm, and dry) meats are major indicators of those welfare problems in pigs (27). However, it should be emphasized that good performances do not guarantee an optimize welfare (19). In addition, it is difficult for farmers with high work intensity to continuously record the accurate performance of animals on farm.

1.2.2.2. Health

As the health of an animal is a state in which it attempts to cope with pathology that come from its environment (28); health is an important part of animal welfare. Health state is some of the most serious welfare problems for farm animals (29); health refers to the state of the body and brain in relation to the effect of pathogens, parasites, tissue damage or physiological disorders (19). The appearance of injuries or diseases is an obvious indicator of poor welfare, and these diseases mainly depend on environmental combinations such as management, housing, and hygiene conditions of the farm. Health indicators have the advantage of being more easily validated than other types of indicators because they are the result of suffering (19). When assess the welfare of farms, the health indicator should be carefully considered (30).

1.2.2.3. Physiology

Diseases, injuries, and impaired growth and reproduction resulting from failure to cope with the environment are clear indicators of poor welfare (9), but physiological responses resulting from cope with challenges can also be seen as indicators of poor welfare (31).

Heart rate and stress hormones are the main physiological indicators of animal welfare measurements. Although Heart rate is a fast response to environmental changes, it is affected not only by stress response but also by various activities of animals, the results should be interpreted considering the level of activity of animals. The Hypothalamic-Pituitary-Adrenal (HPA) Axis has been widely used as an indicator of stress. There is clear evidence that the level of adrenaline, noradrenaline, and glucocorticoid increases in response to acute stress (e.g., transport, tail docking, castration, dehorning, and mixing of unfamiliar animals) However, the effect of chronic stress on the activity of the HPA axis is unclear. Physiological parameters have several limitations. Physiological changes are difficult to interpret and are not always related to poor welfare. Similar changes in physiological responses can occur in situations of opposite affective states (e.g., cortisol, (32)). Second, there are individual differences in physiological variables, and some parameters may appear differently depending on the circadian pattern (33). Finally, physiological parameters are difficult to measure on farm, and since invasive and special materials are required for sampling, the stress of the animals during the handling may reduce the validity of the data. Using methods that do not induce stress in animals in the process of obtaining samples allow physiological parameters to be used as tools to assess animal welfare along with other factors such as performance, health, and behavior.

1.2.2.4. Behavior

Behavior often represents an animal's first response to stressful environments (19) and is commonly used parameter to assess pain on farms (34). Examples of behaviors representing pig pain include lack of movements and normal social behaviors (35). In addition to pain related behaviors, other changes in duration and frequency of normal behavior are perceived as indicators of psychological distress (e.g., frustration). Signs that may arise from stress include frighten or defensive responses, avoidance, suppression of feeding and sexual behavior, excessive aggression, and stereotypic behavior (36). Behaviors such as pecking hen's feathers or biting pig's tail are abnormal behaviors caused by lack of exploratory activities that may easily lead to pain. Therefore, exploration is essential for the normal behavior of farm animals, and the evaluation of the exploratory activity as well as the frequency of abnormal behavior of animals can be used as an indicator of welfare (19). The evaluation of multiple behaviors can be useful indicators and predictors of physical and mental suffering. However, before reaching the state of pain or chronic stress, it should evaluate "if the animals actually have what they want" as Dawkins (1) argued, and then remove subtle causes that may impair welfare, and be meticulously aware of needs for the animals (19).

1.2.3. Environment-based vs animal-based measures

The scientific evaluation of animal welfare is essential for improving animal welfare. Many scientists have conducted research to evaluate animal

welfare scientifically and accurately. Animal welfare is multidisciplinary (7), we cannot evaluate an animal's welfare directly using a single measure; at the present, no one category of measurement seems adequate to measure the multidimensional aspects of welfare, and it is the general opinion that the most valid assessment of an animal welfare is obtained when parameters from both types of measurements are used in combination (21). In the present study, we evaluated the welfare of growing pigs in South Korea using animal- and environment-based parameters to determine whether environment-based parameters, particularly, air quality parameters, can be used as indicators of minimum animal welfare standards.

1.2.4. Welfare quality assessment methods

As described above, there are animal- and environment-based parameters in the animal welfare assessment method, animal welfare assessment methods are developed alone or in a combination of those two parameters. The proportion of the two types of parameters mixed varies depending on the welfare assessment method. Most of the welfare assessment methods were developed in Europe. They all assess animal welfare, but they have different goals (21). However, there is no single clearly defined goal for herd level welfare assessment; the goals vary depending on methods of welfare assessment, and some methods also provide more than one goal (21). An overview of these system evaluating cattle, pigs, and poultry is described below and resumed in Table 1.

1.2.4.1. 35L and ANI 200

The “Animal Needs Index,” “Tiergerechtheitsindex” (TGI), was developed in Austria during the 1980s into ANI 35L (37). It was reworked in Germany in 1994 into ANI 200 (38). Index systems have been developed for assessing welfare in cattle, pigs, and laying hens, especially regarding organic production. The parameters are recorded on the farm in about an hour by specially trained inspectors, and these scores are summarized in an overall welfare score. In general, index systems are very intuitive (39), highly practicable, and highly repeatable (40). The index systems are very popular and are easily understood by non-scientists, at least in their general principles (21). TGI 35L and TGI 200 have much in common, but they have different backgrounds and systems. The details of two systems are as follows:

ANI 35L

The ANI 35L was developed to certify the level of animal welfare on farms. Today it is used to control organic farming in Austria. The ANI 35L points are assigned to five areas regarding housing system and management: 1) possibility of movement, 2) social contact, 3) quality of floor, 4) climate, and 5) stockman care. Very restrictive housing systems, such as battery cages for laying hens, cannot be evaluated with the ANI 35L because of its certain minimum standards in the scoring system (e.g., minimum space requirements). The TGI 35L is categorized as 6 levels: “not suitable” (less than 11 points), “scarcely suitable” (11-15 points), “somewhat suitable” (16-20 points), “fairly suitable” (21-24 points), “suitable” (25-28 points), and “very suitable” (higher than 28 points). Existing organic farms in Austria require a

minimum score of 21 points and new housing systems require higher than 24 points (41).

ANI 200

The ANI 200 was developed for on-farm welfare assessment that can be compared between farms. Its purpose is to provide advice and support to livestock farmers on how to improve animal welfare (38). ANI 200 scores are assigned to 7 different aspects of 1) locomotion, 2) feeding, 3) social behavior, 4) resting, 5) comfort, 6) hygiene and 7) stockman care. Up to 200 points can be earned in a loose housing system with access to pasture. The ANI 200, like the ANI 35L, cannot evaluate the welfare quality assessments in restricted farming system (e.g., stalls for sows and battery cages for laying hens).

1.2.4.2. Ethical Account

In the project "Development of Ethical Account for Animal Husbandry," a welfare assessment method, Ethical Account was developed for dairy and pig farms in Denmark (41). The method aimed to provide the farmer with detailed information about welfare status on the farm. The welfare assessments were based on information from four categories: 1) the housing system, 2) the management, 3) records of animal behavior, and 4) records of health (i.e., records of clinical symptoms and centrally registered health data). The environmental, management, and behavioral parameters were recorded biweekly by trained observers, and each recording session was performed for one hour to one hour and 30 minutes depending on the

size of the herd. In addition, tests to measure fear of humans were performed four times a year. A veterinarian performed clinical examinations of all animals in the herd for one hour to one hour and 30 minutes every fourth month and collected routinely recorded records of veterinary treatment. Welfare assessment results were presented to the farmer in an annual welfare report consisting of individual measurements and comprehensive description of welfare status on the farm. Through the annual welfare report, the farmer was able to learn about changes in animal welfare status since the previous year and about how to improve the animal welfare.

1.2.4.3. Decision support system

A method proposed by Bracke et al. (42,43) in the Netherlands was designed to assess, and guide decisions about which promotes animal welfare. Together with a description of the housing system, the method aimed to calculate an overall welfare score which was based on a combination of scientific data on how individual environmental factors effect. This model is implemented as a computer-based decision support system that receives a description of the housing and management system as input and calculates welfare scores as output. This method was based on scientific research and focuses on welfare assessment of housing systems and uses a model developed for pregnant sows in crates. This model contains 37 attributes that describe the welfare-related indicators of housing and management systems (Figure 1). In the decision support system these attributes are linked to scientific statements and a list of needs to provide

Table 1. Method of assessment of farm animal welfare at farm level

Name of assessment	Title of assessment project	Animals	Development years	Aim of assessment	Result of assessment	Country
ANI 35L	Tiergerechtheitcindex (TGI) 35L	Cattle, pigs, laying hens	1980s	Certification of housing in respect to welfare in organic farming	Welfare score	Austria
ANI 200	Tiergerechtheitcindex (TGI) 200	Cattle, pigs, laying hens	1994	Certification of housing in respect to welfare in organic farming	Welfare score	Germany
Ethical account	Development of Ethical Account for Animal Husbandry	Cattle, pigs	1997	To provide an advisory tool for the farmer	Welfare report	Denmark
Decision support system	Decision support system to assess the welfare status in farm animals	Pigs (cattle, laying hens)	1999~2002	Evaluation and welfare on individual farms	Welfare score	The Netherlands
Benchmarking system	Animal-Based Welfare Assessment of group-housed calves	Cattle (pigs, laying hens)	2000~2001	To compare farms/ To provide an advisory tool for the farmer	Welfare rank	UK
On-farm assessment of dairy cows' welfare	Group-housed calves on UK Dairy farms	Cattle (pigs, laying hens)	2001	To compare farms/ Certification or labelling schemes	Welfare score	France
Welfare Quality® assessment protocol	Welfare Quality® project	Cattle, pigs, laying hens	2004~	To compare farms/ Evaluation and welfare on individual farms	Classification of welfare level	EU

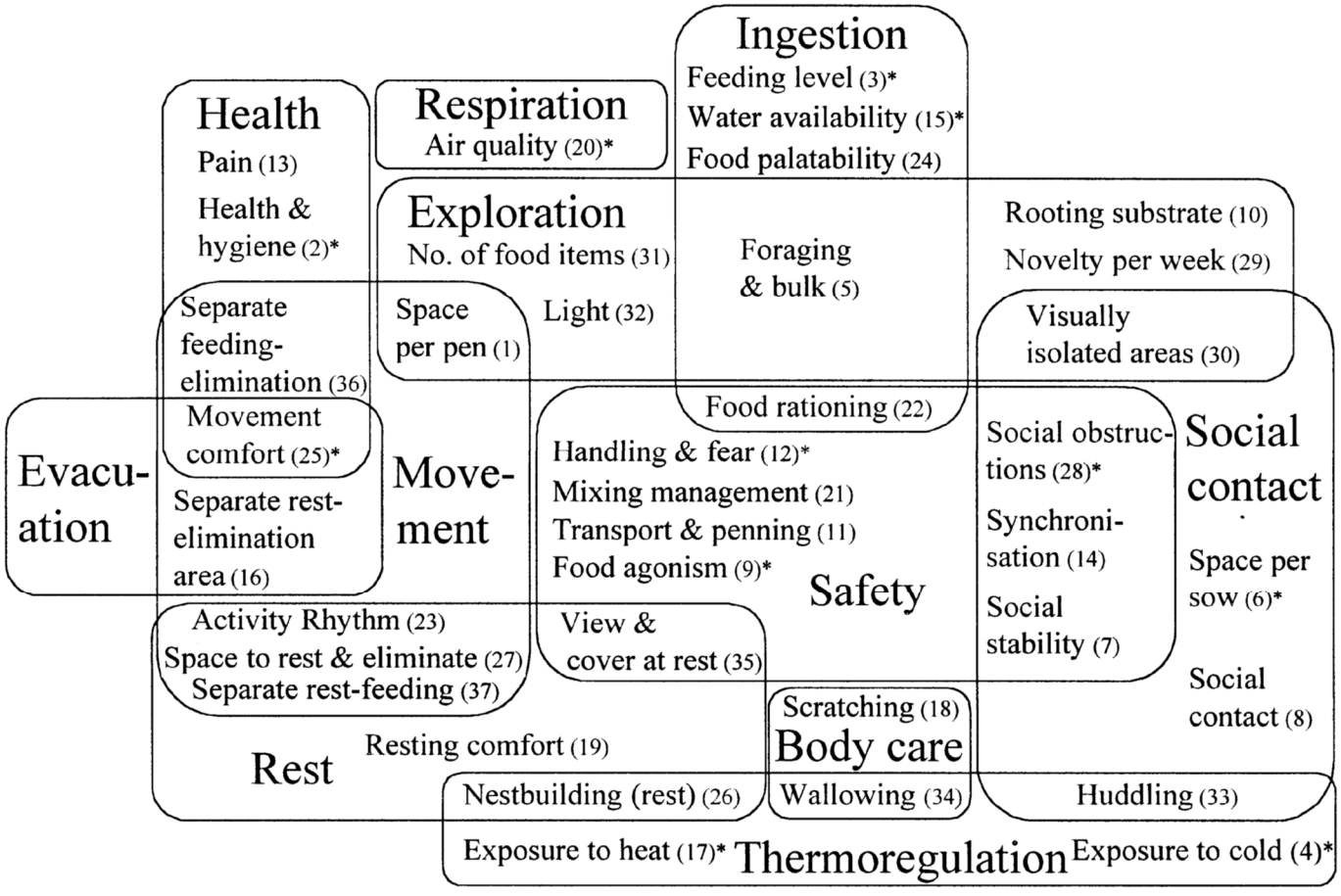


Figure 1. Diagram showing how the attributes in the model are linked to the 11 (welfare) needs that cover pregnant sow welfare overall. *Identifies attributes that contain a minimum-requirement level for welfare.

a scientific basis for welfare assessment; however, according to the author, it could be applied to all farm animal species and any housing system, but it remains to be seen whether this method can also be used to assess animal welfare at a farm level (21). The aggregation method is an implicit score summation, and like the index system, there is a limit to which compensation is allowed.

1.2.4.4. Benchmarking system

Whay et al. (44) compared the welfare of dairy calves on 45 farms on 19 animal-based measures corresponding to respiratory health, nutrition, and general appearance. Based on the results, each farm, were ranked from the best (rank 1) to the worst (rank 45). This method is clear and easy to understand and standardize and can help farmers to know the welfare position of their farm among others and make them understand the welfare status of their animals (39). However, since this method depends on the population observed, even the same farm can obtain different rankings in the different populations, so there is a limit to showing relative results (45).

1.2.4.5. On-farm assessment of dairy cows' welfare

In contrast with ANIs, the method was based on observations of animals and developed in a research project in France. It uses a multidimensional approach based on the five freedoms (2), which can be exploited to evaluate animal welfare on farms (46); five freedoms: 1) freedom from hunger and thirst, 2) freedom from discomfort, 3) freedom from pain and

injury, 4) freedom from fear, and 5) freedom to express normal behavior. These were further subdivided into 16 basic needs. A list of the 49 welfare-indicators, most measured in animals (e.g., behaviors, injuries) was produced. Each pattern was rated on a value-scale regarding any need. With these bases, any pattern could be scored for a given herd by determining the frequency within a herd reflecting a very low, low, high, or very high level of welfare. For all patterns of a particular index, the scores obtained by the herd were integrated into a single score for that index. To this end, they defined logical rules that limits the compensation between scores.

1.2.4.6. Welfare Quality® protocol

With the growing consumer interest and demand for information on animal welfare (47), interest in developing a multidimensional and understandable welfare assessment system based mainly on animal-based indicators has increased. Accordingly, the EU funded a large-scale project, Welfare Quality® that aims to produce a European standard for welfare assessment (48). These include the animal welfare index ANI 35L in Austria (37) and the related ANI 200 in Germany (38), the ethical account in Denmark (41), Freedom Food schemes in the United Kingdom (RSPCA), a decision support system for overall welfare assessment of sows in The Netherlands (42,43), and On-farm assessment of dairy cows' welfare in France (46) and Italy (49). Welfare Quality® presented a multidimensional framework for evaluating welfare in order to overcome the limitations of the already established animal welfare evaluation protocol. A set of measures, mainly

based on the direct observation of animals, has been selected from the literature and has been evaluated in pilot studies for its independent validity, repeatability and feasibility (19). A detailed description of the Welfare Quality® protocol will be discussed in Chapter 2.1.2.

1.3. Situation on pig welfare

Over the past 50 years, pig farms in the European Union (EU) have become increasingly intensive, which means that the number of pig farms in the EU has decreased and the number of pigs per farm has dramatically increased (50,48). To meet the needs of consumers who want to buy cheap pork, more and more pigs have been moved to indoor housing systems with high stocking density and use of preventive drugs and growth promoters has increased (51,52). As reports have been made that the welfare of farm animals raised in intensive farming systems is vulnerable (51,53), citizens' interest in farm animal welfare has increased (54), and many studies have been conducted on farm animal welfare over the past 20 years (55,56). These were used as evidence of policy debates (57) or legislation introduction (58), leading to the public's demand for stricter standards for farm animal welfare.

Pigs are the most commonly, intensively reared mammals in the world (59), with 1.3 billion pigs slaughtered for meat each year worldwide (60). Although legislation for the welfare of pigs in the UK exceeds the requirements of EU legislation, it does not solve all welfare issues associated with conventional pig production system (50). In Korea, as in Europe, pig

farms have changed to intensive systems, and while the number of pig farms has decreased sharply from 16,148 in 2003 to 5,636 in 2013 and 4,585 in 2017, the number of pigs raised in large pig farms with more than 10,000 pigs has increased significantly from 698,337 pigs in 2003 to 1,775,271 pigs in 2013 and 2,039,339 pigs in 2017 (61) (Table 2). As shown in Figure 2, the distribution of the number of pig farms raising less than 1,000 pigs decreased by about 50% from 82% in 2003 to 48% in 2013 and 39% in 2017, and the distribution of the number of farms raising 5,000 to 10,000 pigs increased about 5 times from 0.8% in 2003 to 4.4% in 2013 and 6.7% in 2017. In addition, the distribution of the large-scale pig farms raising more than 10,000 pigs increased about 6 times from 0.3% in 2003 to 1.8% in 2013 and 2.6% in 2017. This appears to be due to the disappearance of the barrier that prevented large corporations from entering the livestock industry with the abolition of the Livestock Act of large corporations in 2010. With the increase of livestock industry of large corporations, the number of small-scale farms (> 1,000 pigs) decreased sharply. Prior to 2017, the statistic was surveyed using the Census of Agriculture, Forestry and Fisheries, which is a complete survey targeting agricultural, forestry and fishermen. However, after 2017, the survey was conducted based on the traceability system, which is a report on the breeding status of livestock breeding facilities to which farm identification numbers are assigned. The population has changed as of 2017, so data up to 2017 are presented in the present study.

In South Korea, although the economy and livestock industry have developed rapidly over the last few decades, public awareness of farm animal welfare has only recently begun. Animal welfare issues are receiving

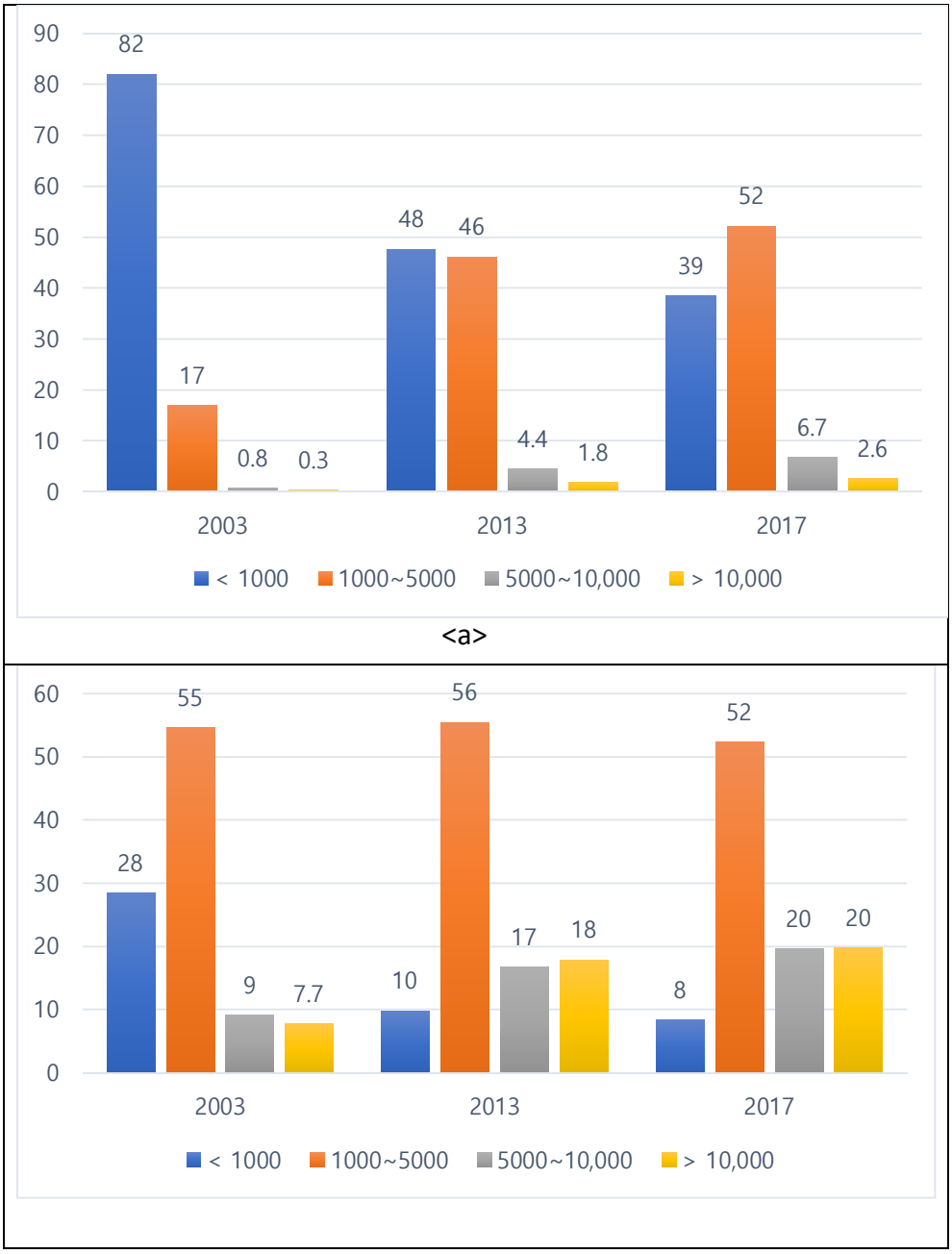


Figure 2. Distribution of the number of pig farms and pigs in South Korea in 2003, 2013, and 2017 <a> Distribution of the number of pig farms <b> Distribution of the number of pigs

Table 2. The number of pig farms and pigs in South Korea in 2003, 2013, and 2017

Farm size	Number of farms			Number of pigs		
	2003	2013	2017	2003	2013	2017
< 1000	13,237	2,684	1,766	2,568,254	973,123	854,555
1000~5000	2,737	2,602	2,394	4,932,484	5,504,409	5,407,318
5000~10,00	125	250	307	827,500	1,659,401	2,026,454
> 10,000	49	100	118	698,337	1,775,271	2,039,339
Sum	16,148	5,636	4,585	9,026,575	9,912,204	10,327,666

an increasing amount of public attention in South Korea due to public campaigns by non-governmental organizations. However, few studies have assessed the welfare of pigs in South Korea. Wu is proposing several policy tasks to farm animal welfare in his study (62), and the first proposal is to expand scientific research on farm animal welfare. Since there were not many studies related to farm animal welfare in South Korea, there is a lack of scientific and objective data necessary for policy establishment, so the expansion of related studies is required to promote a system suitable for our situation. Several studies have been conducted on farm animal welfare in South Korea. However, most of the study on farm animal welfare was related to policy direction or economic performance (62,63,64,65,66), and there were few studies on evaluation of farm animal welfare. Research by Renggaman et al. (67) was only conducted on two pig farms in South Korea, using animal-, resource, and management-based parameters, which is insufficient to evaluate the greater, country-wide welfare status of pigs.

As the public's interest in animal welfare increased, the first animal-cruelty legislation of South Korea, the Animal Protection Act, was enacted on

May 31, 1991, by the South Korean legislature. The ratification of this Act was a historical first step toward South Korean animal rights. The stated purpose of the Animal Protection Act (2021) (68) is to prescribe matters necessary to prevent animal abuse and to properly protect and manage animals, and thus contribute to protecting the lives of animals and enhancing their safety and welfare, as well as developing national ethos, such as respect for their life, and facilitating a harmonious coexistence between humans and animals through creating a sound and responsible raising culture (Article 1). All citizens must comply with the Five Freedoms for animals (Article 3), and the government must establish a national animal welfare plan (established every five years) in accordance with Article 4. Animal welfare plans are supported and implemented by local governments. Similarly, Article 5 established an animal welfare committee within the Ministry of Agriculture, Food and Rural Affairs. Both are responsible for ensuring the prevention of animal abuse. The Committee is required to include veterinarians, animal welfare NGO representation and animal welfare policy experts. Article 7 of the Animal Protection Act creates a duty of care, requiring that owners and keepers of animals provide appropriate feed and water and endeavor to ensure that the animal exercises, rests and sleeps adequately. The Animal Protection Act also mandates the protection of some cruelty to animals during transportation and states that animals must not be slaughtered in a cruel or revolting ways and that there must be no unnecessary pain, fear, or stress in the process. Similarly, anyone who works with animals (as defined in Article 32) should receive an annual education on animal protection. While the Animal Protection Act has continued to improve

due to the public's interest in animal welfare and the active promotion of the government, animal welfare, particularly, the welfare of farm animals, is still very insufficient. This is because, firstly, the definition of animals in the Animal Protection Act contradicts that of animals in other laws, so its application may still be unclear. This is a common theme across animal-related legislation in South Korea. For example, it is unclear how the protections enshrined in the Animal Protection Act, such as the Five Freedoms, are applied in relation to farm animals. Secondly, it cannot be assessed whether the conditions of intensive farms (e.g., high stocking density, use of stall for sow, and tail docking or castration with anesthetic) cannot achieve some of the five freedoms stipulated in the Animal Protection Act. In fact, although the Animal Protection Act was enacted, there is no system to evaluate whether it is well observed or whether the welfare of animals has been improved.

After the Animal Protection Act enacted in 1991 was completely amended in February 2012, the farm animal welfare certification system for laying hens began in March, and the certification system was expanded to pigs in 2013, to broiler in 2014, to cows and goats in 2015 and to ducks in 2016. Although there are standards for evaluating the animal welfare certified farms, most of them are environment-based parameters, so it is difficult to expect accurate evaluation of animal welfare. In addition, to improve the breeding environment of livestock farms, a new animal welfare-type breeding standard (group housing) has been introduced for pig farms, and policies are being established to apply from 2019 for new farms and from 2029 for

existing farms. This restricts the use of a stall for sow after 6 weeks of gestation.

Yang et al. (69) mentioned the excellence of the Welfare Quality® protocol and indicated that South Korea also desperately needs a reliable science-based system to evaluate the welfare status of livestock. As pointed out by Yang et al., there is no system in Korea to evaluate the welfare of farm animals, and there is no assessment protocol suitable for the Korean situation.

The farm environment is a complex dynamic system that is influenced by many factors affecting the health and welfare of the animals. In fact, this is the case for many intensively reared animals raised in traditional, conventional livestock system. Important measurement parameters include temperature, relative humidity, ventilation, concentration of gases, airborne bacteria, and particulate matter (70,71,72). Particulate matter, airborne bacteria, and gases are the most significant factors that affect animals in the aerial environment of the pig house, and their impact depends on both animal management practices and the pig housing structure (73). These environment-based parameters are considered as the major factors influencing the welfare of pigs on commercial farms.

Therefore, it is very important to establish an animal welfare assessment protocol that is suitable for Korea and easy to use by evaluating the welfare of growing pigs using animal- and environment-based parameters.

1.4. Purpose of this study

The purpose of this study was 1) to evaluate the welfare status of growing pigs in South Korea using the Welfare Quality ® protocol, an animal-based assessment protocol, 2) to find out the current status of the welfare quality of South Korea by comparing the welfare assessment results between South Korea and the European nations, and 3) to use it as the basis for developing an animal welfare assessment protocol suitable for South Korea by understanding the relationship between animal- and environment-based parameters.

Chapter 2. Method and Results

2.1. Method

2.1.1. Study farm

This study assessed nine intensive growing pig farms situated in three South Korean provinces during the winter of 2013 (Figure 3). These three provinces have the largest number of pig farms in South Korea: Gyeonggi-do, Gyeongsangbuk-do, and Chungcheongnam-do (61). According to South Korean pig statistics, there were 2,602 pig farms with sizes ranging between 1,000 and 5,000 pigs in 2013 (61). The total number of pigs raised on these farms was 5,504,409, which corresponds to 56% of all pigs in South Korea. Of the nine farms evaluated in this study, eight (88 %) raised between 1,000 and 5,000 pigs, and one (11 %) raised fewer than 1,000 pigs. Details of the pig farms are summarized in Table 3.

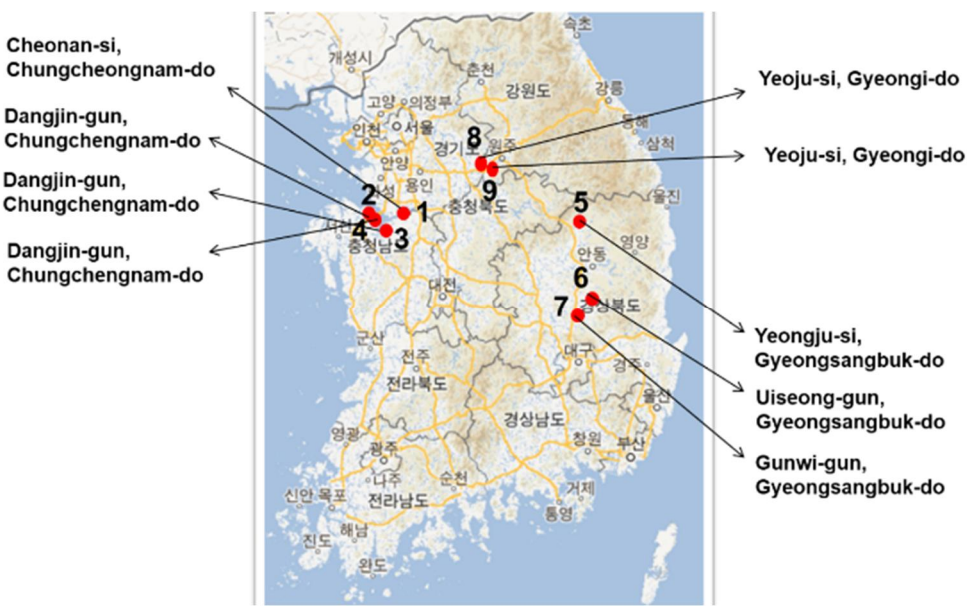


Figure 3. The location of pig farms assessed with the Welfare Quality® protocol in South Korea

Table 3. The details of nine pig farms assessed in South Korea

No.	Floor type	BT[1]	NPF[2]	SAP[3]	SAK[4]	NPP[5]	AW[6]	AA[7]
1	Partly slatted concrete floor	B[8]-F [9]	3500	0.8	1.3	18	60	81
2	Partly slatted concrete floor	B-F	5000	0.4	0.7	150	60	80
3	Partly slatted concrete floor	B-F	2000	0.4	1.8	13	25	42
4	Partly slatted concrete floor	F	450	1.0	2.1	10	45	66
5	Fully slatted concrete floor	B-F	1500	1.1	2.2	30	50	70
6	Partly slatted concrete floor	B-F	2900	0.7	1.8	40	40	62
7	Sawdust	F	2000	1.8	4.0	30	45	63
8	Partly slatted concrete floor	B-F	4000	0.4	1.1	40	40	60
9	Sawdust	B-F	2000	0.7	1.5	60	45	65

[1] Breeding type, [2] Number of pigs in the farm, [3] Space allowance (m^2)/pig, [4] Space allowance (m^2)/100kg, [5] Number of pigs/pen, [6] Average weight(kg), [7] Average ages (days), [8] Breeder, [9] Fattener

Pigs were kept in pens of 10–150 animals; the mean number of pigs per pen was 43.3 ± 42.88 pigs (30.1 ± 16.6 pigs when excluding the farm with 150 pigs). The average space allowance in a pen ranged from 0.7 to 4 m^2/100 kg (mean ± SD = 1.82 ± 0.95 m^2/100 kg) and from 0.42 to 1.8

m^2/individual (mean ± SD = 0.81 ± 0.44 m^2/individual). The age of the pigs within a single pen ranged from 42 to 81 days of age (mean ± SD = 65.44 ± 10.74 days) and the body weight in a pen ranged from 25 to 60 kg (mean ± SD = 45.56 ± 19.97 kg). For six out of nine farms, the space allowance was above 0.45 m^2; this is above the requirements for permission and registration of livestock industry in the Enforcement Decree of the Livestock Industry Act (74). Although the space allowance on six farms was above the minimum standards, it remained far below the minimum standard of 0.8 m^2 for fattening pigs, considering that they were raised in the same space until they moved to the slaughterhouse (all-in-all-out system). Four out of nine pig farms had a mechanical ventilation system and five had a natural ventilation system. During the assessment, because of the cold weather, there were no fans operating in the pig houses with mechanical ventilation systems. The house with a natural ventilation system were covered with a thick, heavy curtain. Seven pig farms had slatted concrete floors without bedding materials (six farms were partially slatted and one farm was fully slatted), two farms had sawdust floors. Prior access permissions were obtained from farm owners, and they allowed post-visit contact for questions regarding the farm operations.

2.1.2. Animal-based parameters

Welfare Quality® Protocol is an animal-based and on-farm welfare assessment protocol designed for intensive farms, co-financed by the

Table 4. The principles and criteria of the Welfare Quality® protocols

Principle	Criteria	Measures
Good feeding	1 Absence of prolonged hunger	Body condition score
	2 Absence of prolonged thirst	Water supply
Good housing	3 Comfort around resting	Bursitis, absence of manure on the body
	4 Thermal comfort	Shivering, panting, huddling
	5 Ease of movement	Space allowance
Good health	6 Absence of injuries	Lameness, wounds on body, tail biting
	7 Absence of disease	Mortality, coughing, sneezing, pumping, twisted snouts, rectal prolapse, scouring, skin condition, ruptures, and hernias
	8 Absence of pain induced by management procedures	Castration, tail docking
Appropriate behaviors	9 Expression of social behaviors	Social behaviors
	10 Expression of other behaviors	Exploratory
	11 Good human-animal relationship	Fear of humans
	12 Positive emotional state	Qualitative behaviors assessment (QBA)

European Commission from 2004. Welfare Quality® protocol involved 44 institutions and universities representing 13 European countries and 4 Latin American countries. All measures were evaluated in a pilot study for their independent validity, repeatability and feasibility, and the final monitoring protocol was tested on a commercial pig farm. It has addressed key welfare

Table 5. Measures with their respective scoring scale and description used in the welfare assessment

Measures	Score	Description
Body condition	0	Animal with a good body condition
	2	Poor body condition: Animal with visible spine, hip, and pin bones
Water supply	0	Number of drinking places are enough/ Function correctly and clean
	2	Number of drinking places are not enough/ Do not function properly / dirty
Bursitis	0	No evidence of bursa / swelling
	1	Moderate bursitis: One or several small bursae (1.5-2.0 cm) on the same leg or one large bursa (3.0-5.0 cm)
	2	Severe bursitis: Several large bursae on the same leg, or extremely large bursa (5.0-7.0 cm) or any bursas that are eroded
Manure on the body	0	Less than 20% of one side of the body is soiled
	1	Moderately soiled body: More than 20% but less than 50% of one side of the body surface is soiled with feces
	2	Severely soiled body: Over 50% of one side of the body surface is soiled with feces
Shivering	0	No vibration of any body part
	2	Slow and irregular vibration of any body part, or the body as a whole
Panting	0	Normal breathing.
	2	Rapid breath in short gasps
Huddling	0	Pig lying with less than half of its body lying on top of another pig
	2	Pigs lying with more than half of its body lying on top of another pig
Space allowance		Space allowance expresses in m2 / 100 kg animal
Lameness	0	Normal gait or slight difficulty but using all 4 legs; swagger of caudal body while walking; shortened stride
	1	Severely lame, minimum weight-bearing on the affected limb
	2	No weight-bearing on the affected limb, or not able to walk
Wounds on body	0	If all regions of the animal's body have up to 9 lesions in one side of the body
	2	Severely wounded: when more than 10 lesions are observed on at least two zones of one side of the body or if any zone has more than 15 lesions

Tail biting	0	No evidence of tail biting or superficial biting along the length of the tail, but no fresh blood or any swelling missing and presence of scabs
	2	Bleeding tail and / or swollen infected tail lesion and / or part of tail tissue
Mortality	%	Percentage mortality during the previous 12 months
Coughing		Average frequency of coughing per animal per 5 minutes
Sneezing		Average frequency of sneezing per animal per 5 minutes
Pumping	0	No evidence of laboured breathing
	2	Evidence of laboured breathing
Twisted snouts	0	No evidence of twisted snouts
	2	Evidence of twisted snouts
Rectal prolapse	0	No evidence of rectal prolapse
	2	Evidence of rectal prolapse
Scouring	0	No liquid manure visible in the pen
	1	Areas in the pen with some liquid manure visible
	2	All feces visible inside the pen is liquid manure
Skin condition	0	No evidence of skin inflammation or discoloration
	1	Localized skin condition: More than zero, but less than 10% of the skin is inflamed, discoloured, or spotted
	2	Widespread skin conditoin: More than 10% of the skin has an abnormal colour or texture
Ruptures and hernias	0	No hernias / ruptures
	1	Hernias or ruptures present, but the affected area not bleeding, not touching the floor, and not affecting locomotion
	2	Bleeding lesions, hernias / ruptures and they are touching the floor
Castration	0	No castration done
	1	Castration with use of anesthetics
	2	Castration without use of anesthetics
Tail docking	0	No tail docking done
	1	Tail docking with use of anesthetics
	2	Tail docking without use of anesthetics
Hernias	0	0 No hernia/rupture
	2	2 Hernias/ruptures with bleeding lesion or touching the floor
Social behaviors	%	Negative social behavior: Aggressive behavior, including biting or any social behavior with a response from the disturbed animal

	%	Positive social behavior: Sniffing, nosing, licking, and moving gently away from the animal without an aggressive or flight reaction from this individual
Explorative behavior	%	Sniffing, nosing, licking all features of the pen or paddock. Exploration towards straw or other suitable enrichment material.
Fear of human	0	No panic response to human presence
	2	Panic response: More than 60% of the animals fleeing, facing away from the observer, or huddled in the corner of the pen
QBA[1]	Rating scale	Active, relaxed, fearful, agitated, calm, content, tense, enjoying, frustrated, sociable, bored, playful, positively occupied, listless, lively, indifferent, irritable, aimless, happy, distressed

problems perceived as important by European stakeholders, including producers, retailers, academics, government, and the public. Welfare Quality® protocol (75) was used to evaluate the welfare status of nine growing pig farms using animal-based parameters. Welfare Quality® protocol consists of an assessment using 12 criteria within four main principles: “good feeding,” “good housing,” “good health,” and “appropriate behaviors.” Each of these criteria has specific measures for calculating scores (Table 4). Table 5 describes the respective scoring scale and description of each measure used in the welfare assessment. The order of recorded measures, sample size, location, and time required are shown in Table 6. Welfare Quality® protocol was assessed by two observers. The two observers had identical training prior to the assessment to minimize any differences between observers. Observers obtained prior access permissions from farm owners. The two observers ensured that there was no previous contact between pigs and the assessor for at least 48 h prior to the assessment. The details for calculation of scores for growing pigs on farm is shown in Appendix 1.

Table 6. Order of recorded measures, sample size, place and time required

Information collected	Sample size	Place	Time required
Management-based measures	-	Animal unit manager	10 minutes
Qualitative behavior assessment (QBA)	2 to 8 Points of observation	PENS C	20 minutes
Coughing	6 Points of observation: minimum 2 pens	PENS A or B	15 minutes
Sneezing			
Social behavior	3 Points of observation 50-60 animals/point	PENS A	30 minutes
Exploratory behavior			
Outside the pen:	150 pigs from 10 different pens/groups (15 pigs per pen/group). When > 15 animals per pen/group, 15 animals per pen/group will be randomly chosen and marked before assessment. If there are less than 10 pens/groups, the number of pigs inspected inside each pen/group should be increased until reaching a total of 150 animals	PENS B	60 minutes
Huddling			
Shivering			
Panting			
Inside the pen:			
Fear of humans			
Body condition			
Bursitis			
Absence of manure on the body			
Wound on the body			
Tail biting			
Lameness			
Pumping			
Twisted snouts			
Rectal prolapse			
Scouring			
Skin condition			
Ruptures and hernias			
Water supply	-		
Space allowance			

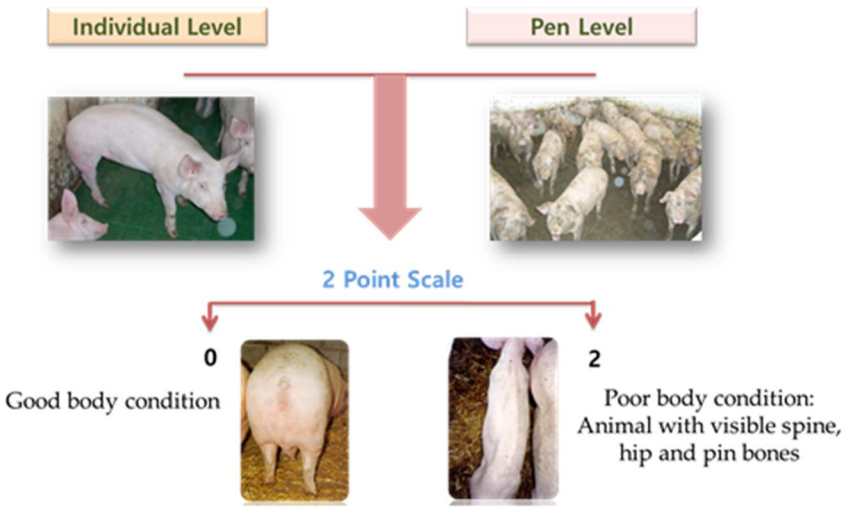
2.1.2.1. Overall assessment

After animals were observed, an overall assessment was carried out at the farm level. Four criteria were combined into an overall assessment to

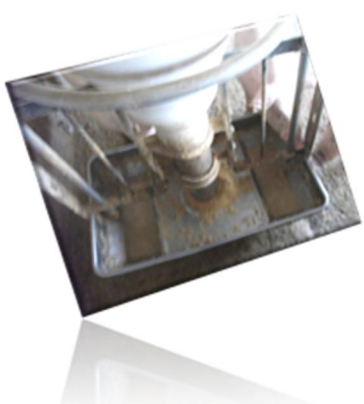
indicate the level of welfare on the pig farms. An overall assessment of the Welfare Quality® protocol can be defined into four categories based on the final score, as follows: “excellent” (80.1–100): the welfare of the animals is of the highest level; “enhanced” (60.1–80): the welfare of the animals is good; “acceptable” (20.1–60): the welfare of the animals is above or meets minimal requirements; and “not classified” (0–20): the welfare of the animals is low and considered unacceptable.

2.1.2.2. Good feeding, good housing, and good health

In this protocol, the welfare status of the pigs is assessed via direct observation, with the exception for the criteria “absence of prolonged thirst” and “ease of movement.” Ten selected pens were assessed throughout the farm; the pens were located evenly across the farm (Table 6). As much as possible, all rooms on the farm were assessed; the hospital pen was not assessed. The welfare parameters were scored at the pen of individual pig level using a three-point scale: 0 for good welfare, 1 for compromised welfare, and 2 for poor welfare. For each parameter, the number of pigs that received a score of 1 or 2 was recorded. In some cases, parameters were recorded using a binary scale: 0 for absent, 2 for present (Table 5). Pigs were individually scored for body condition, bursitis, manure on the body, lameness, wounds on the body, tail biting, pumping, twisted snouts, rectal prolapse, skin condition, ruptures, and hernias. Huddling, panting, shivering, coughing, and sneezing were observed from outside the pens; all other



<Body condition>



- **Number** of drinking places
- **Fucntioning of drinkers**
  0 - The drinker function correctly
  2 - The drinker don't function properly
- **Cleanliness of drinkers**
  0 - Clean
  2 - Dirty

<Water supply>

Manure on the body

0 – Less than 20% of the body surface is soiled

1 – More than 20% but less than 50% of the body surface is soiled

2 – Over 50% of the body surface is soiled

<Manure on the body>

0 – No evidence of bursae

1 – One or several small bursae on the same leg (1.5 - cm diameter) or one large bursa (3.0 - 5.0 cm diameter)

2 – Several large bursae, or one extremely large

<Bursitis>

0 1 2

Individual level -> Herd level

0 – Normal gait or difficulty in walking, but still using all legs; swagger of caudal body while walking; shortened stride

1 – Severely lame, minimum weight-bearing on the affected limb

2 – No weight-bearing on the affected limb, or not able to walk

<Lameness>

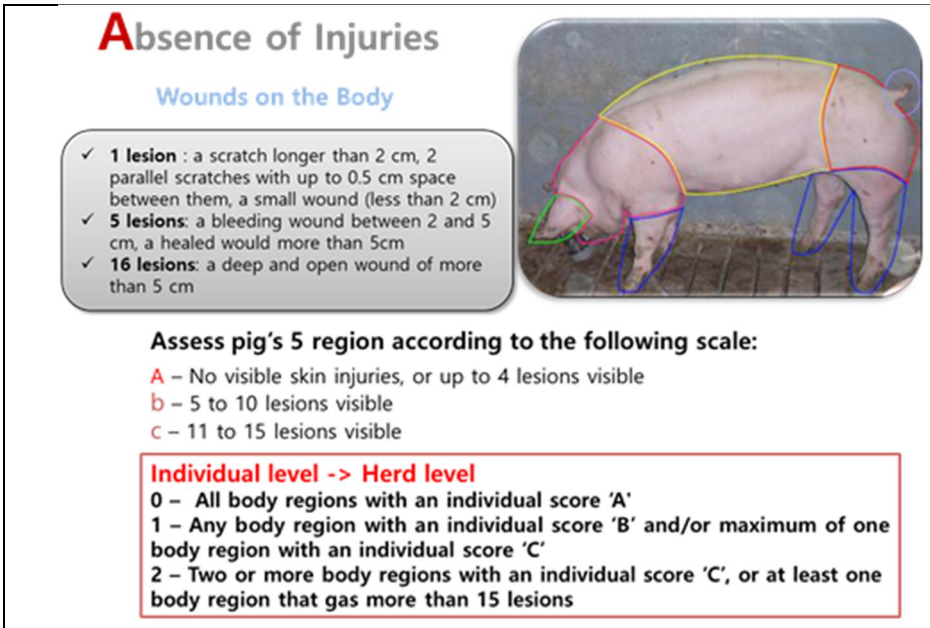
0 0 2

Individual level -> Herd level

0 – No evidence of tail biting or indication of superficial biting along the length of the tail, but no evidence of fresh blood or of any swelling (red areas on the tail are not considered as wounds unless associated with fresh blood)

2 – Fresh blood is visible on the tail; there is evidence of some swelling and infection; part of the tail tissue is missing and a crust has formed

<Tail biting>



<Wounds on the body>

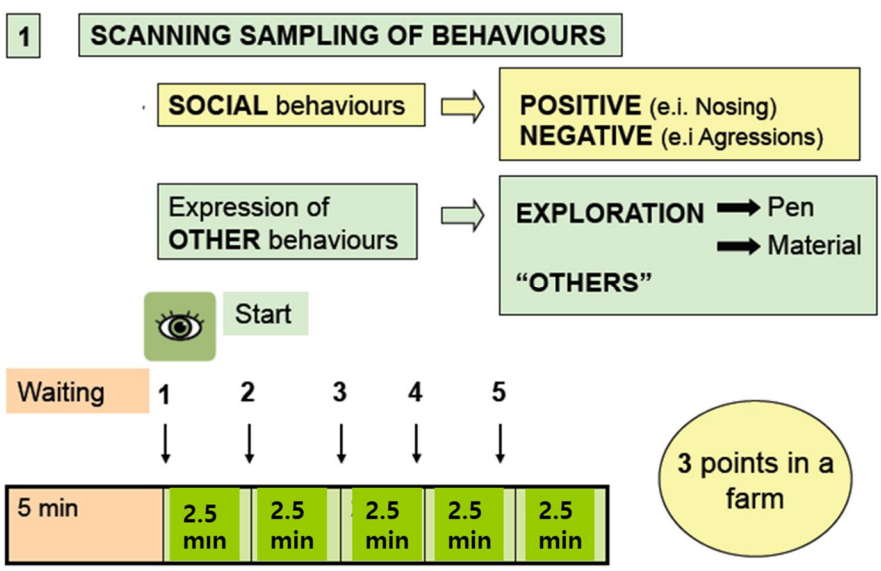
<Hernias>

Figure 4. Major measures with respective scoring scale and description used in the principle "good feeding," "good housing" and "good health" of the Welfare Quality® protocol

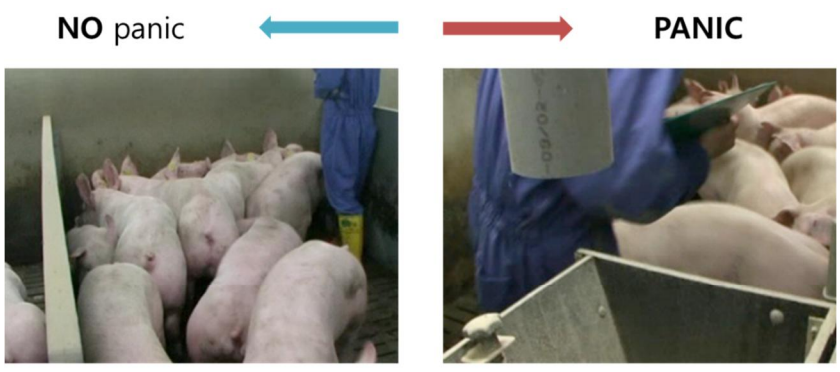
measures were assessed inside the pens to enable careful observation of the pig's bodies. Manure on the body, skin condition, bursitis, and wounds on the body were scored only on one side of each pig, as there are no significant differences in scores between the left and right sides of pigs (76). Major measures with respective scoring scale and description used in the principles "good feeding," "good housing," and "good health" of the Welfare Quality® protocol are shown in Figure 4.

2.1.2.3. Appropriate behaviors

Major measures with respective scoring scale and description used in the principle "appropriate behaviors" of the Welfare Quality® protocol are shown in Figure 5. Two different measures were used for the assessment of "appropriate behaviors": quantitative behavioral assessment and qualitative



<Social and explorative behaviors>



Group level -> Herd level

0 – **Up to 60% of the animals showing a panic response**

2 – **More than 60% of the animals showing a panic response**

<Fear of humans>

<Qualitative behavior assessment>

Figure 5. Major measures with respective scoring scale and description used in the principle "appropriate behaviors" of the Welfare Quality® protocol

behavioral assessment (QBA). Quantitative behavior assessment social and exploratory behaviors and the human-animal relationship (HAR). Social and exploratory behaviors were assessed via scan sampling at three different observation points (76), with approximately 50–60 pigs observed at each observation point. Before beginning the scan, the observer clapped to make all pigs stand up, then, after 5 min, started the scan from outside the pen (Table 6). Each pen was observed five consecutive times with an interval of 2.5 min between scans (76). The HAR was evaluated using the fear of human test (76), in which 10 randomly selected pens were assessed throughout the farm. Any pen with more than 60% of the pigs showing panic toward the human was recorded, where panic was defined as an animal facing away from the observer or huddling in the corner of the pen. When walking through the group the assessor did not interact physically or talk to the animals. Limited physical contact might occur during walking, such as a gentle touch when pigs were very close in front of the observer (76).

QBA considers the expression and environment of how animals behave and interact with each other, i.e., their “body language.” QBA uses descriptive terms with expressive connotations to reflect animals’ situational experiences (77). A rating scale was used to score pigs at the group level at six observation points per farm, based on 20 different terms: terms of positive emotional state; active, relaxed, calm, content, enjoying, sociable, playful, positively occupied, lively, and happy; terms of negative emotional state; fearful, agitated, tense, frustrated, bored, listless, indifferent, irritable, aimless, and distressed (75). For the sampling points, between one and eight observation points (depending on the size and structure of the farm; Figure

6) that together cover the different areas of the farm were selected (75). After deciding the order to visit these observation points, waited a few minutes to allow the animals to return to undisturbed behavior. The observer observed the animals' expressive quality of their activity at group level. When observation at all selected points has been completed, find a quiet spot, and score the 20 descriptors using the visual analogue scale (VAS). We did not score during observation and made only one integrative assessment per farm (75). The scale was of 125 mm length, left side meant the minimum state that the expressive quality indicated by the term was entirely absent in any of the pigs observed, and right side meant the maximum state indicated that the descriptor was dominant across all pigs. Scored within this scale according to the number of animals showing each term used and the percentage of time that animals were observed in each state. The assessment was carried out at farm level after animals in several pens or paddocks had been observed for total 20 minutes (i.e., 8 points of observation and 2.5 minutes per point of observation).

2.1.3. Environment-based parameters

2.1.3.1. Microclimate

All measurements were conducted in triplicate. Temperature, relative humidity, and air speed were measured at nine points inside the pig house at 60 cm above the floor (Figure 6), which corresponds to the nose height of growing pigs (78). Air temperature and relative humidity were measured with a hygrothermograph (SK-110TRH, SATO, Tokyo, Japan) and air speed was measured with an anemometer (model 6112, KANOMAX,

Osaka, Japan).

2.1.3.2. Particulate matter concentrations

Particulate matter concentrations were measured at three points in the aisles (Figure 6), as it would be difficult to keep the instrument (aerosol mass monitor, GT-331, SIBATA, Socacity, Japan) safe from the pigs if it were inside the pen. The mass concentrations of PM_{10} (PM average aerodynamic diameter #10 mm), $PM_{2.5}$ (PM mean aerodynamic diameter #2.5 mm), PM_1 (PM mean aerodynamic diameter #1 mm), and TSP (total suspended particles) were obtained simultaneously.

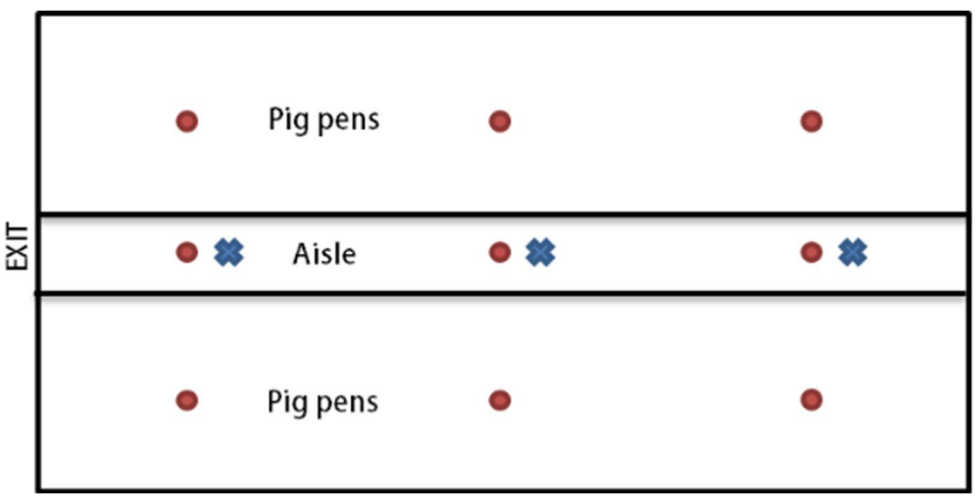


Figure 6. Sampling points for the environment-based parameters.

Sampling points for temperature, relative humidity, and air speed.

Sampling points for concentration of particulate matter, airborne bacteria, and gases (CO_2, NH_3, H_2S).

2.1.3.3. Airborne bacteria

Airborne bacterial counts were measured at three points in the aisles (Figure 6) using the settle plate method; this is a direct method for assessing the likely number of microorganisms depositing onto a product or surface in a given time. The method is based on the fact that, in the absence of any kind of influence, airborne microorganisms, typically attached to larger particles, will deposit onto open culture plates. Tryptic soy agar (Merck, Darmstadt, Germany) was used for enumeration of total airborne bacteria, and Chromocult Coliformen agar (Merck, Darmstadt, Germany) was used for airborne total coliforms and *Escherichia coli*. After sampling, the plates were incubated at 37°C for 48 h, and the colonies were counted and calculated as colony-forming units.

2.1.3.4. Concentration of carbon dioxide, ammonia, hydrogen sulfide

Concentrations of carbon dioxide, ammonia, and hydrogen sulfide were measured using a gas detection device (Gastec, Model 801). A Gastec was used because it is simple to handle and requires a short time to measure several types of gas. Gases from the growing pig houses were measured at three points along the aisle (Figure 6). Concentrations were expressed in ppm.

2.1.4. Comparison the results of the Welfare Quality® protocol between South Korea and the European nation

The results of the assessment of growing pigs in South Korea using

the Welfare Quality® protocol were compared with the results of the one in the European nations calculated by the Welfare Quality® Network (79). The Welfare Quality® Network include data from total of 207 growing pig farms (Finland-83, France-30, Germany-24, Spain-41, and the United Kingdom-29) assessed using the Welfare Quality® protocol over three years from 2009 to 2011. The data of the farm assessment in five European nations in the Welfare Quality® Network include the categories of overall assessment, the average scores of 4 principles and 12 criteria, and the distributions of farms in each stage of the assessment protocol, but not the detailed score for each farm or country. Raw data on each of the 207 pig farms calculated in the Welfare Quality® Network were not shown in the report from the Welfare Quality® Network (79), but have been used in papers of Temple et al. We have researched all the raw data in their paper but could not find any study conducted under a climate similar to that of South Korea. Therefore, we had to only use the distributions of the farms and average scores in each stage of the assessment protocol of the European nations on the present study.

2.1.5. Statistical analysis

Calculations for the welfare scores were conducted online using the calculation model in the Welfare Quality® protocol (79). The final score of each criterion ranged from 0 to 100. Farms were classified according to four

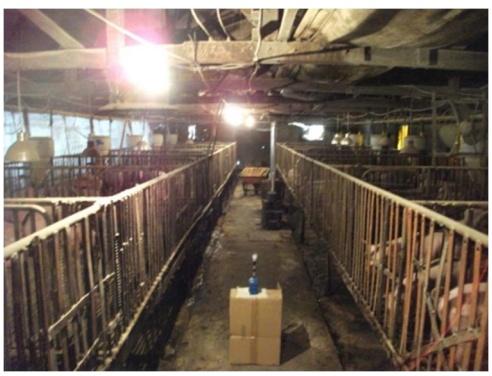
categories based on the final score in each criterion. The statistical evaluation was carried out using SPSS (SPSS Inc., Chicago, IL). Spearman correlation coefficients were calculated between animal- and environment-based parameters. The result of the environment-based parameters were analyzed in order to determine: 1) correlation with the score of the four principles of the Welfare Quality® protocol; 2) correlation with the score of twelve criteria of the Welfare Quality® protocol; and 3) correlation with the result of all the indicator of the Welfare Quality® protocol. To compare the results of the Welfare Quality® protocol between South Korea and the European nations, the data from the Welfare Quality® Network which include total of 207 growing pig farms (Finland-83, Spain-41, France-30, United Kingdom-29, and Germany-24) assessed using the Welfare Quality® protocol over three years (from 2009 to 2011) were used.

2.2. Results

It is an unexpected result that there are no farms categorized as “not classified” according to the classification of the overall assessment in the Welfare Quality® protocol in this study. However, the purpose of this assessment protocol was to find out the “not classified” farms which showed the worst welfare quality of the pigs. Moreover, the standard of the level of “not classified” was set very low in the beginning stage of the protocol (75).

Pictures of the farms evaluated in this study are shown in Figure 7. The environments of all the intensive livestock farm are different, so multiple measures such as the Welfare Quality® protocol are required, and environmental evaluation also be conducted.

<a> A pig house where you can't see ahead with 100% humidity



<b> Particulate matter being measured in the aisle of the pig house

<c> A pig house with low illuminance

<d> A pig house became more uncomfortable because of the wet sawdust

<e> Small sized and well-maintained pig house

<f> A pig house with fewer nipple numbers

Figure 7. Photos of farms evaluated using animal- and environment-based parameters

2.2.1. Animal-based parameters

The results of the Welfare Quality® protocol are summarized in Table 7; the results of the indicators of this protocol are shown in Table 8. Although none of the farms were classified as “excellent” or “not classified," four out of the nine farms were classified as “enhanced” and five were classified as “acceptable” according to the overall assessment. In terms of the average score across the nine farms, the principles, in decreasing order, were “good feeding” (63.13 points) > “good housing” (59.26 points) > “good health” (33.47points) > “appropriate behaviors” (25.48 points). The percentage of farms per category in terms of the Welfare Quality® protocol criteria is shown in Figure 7.

2.2.1.1. Good feeding

In eight out of nine farms, the criterion “absence of prolonged hunger” scored above 90 points (farm 5 scored 75 points). Two farms (farm 3 and 5) scored 100 points for the criterion “absence of prolonged thirst,” but the remaining seven farms scored below 55 points because of poor drinker functionality (Table 8).

2.2.1.2. Good housing

Among the three criteria within the principle “good housing,” the criterion “comfort around resting” scored the lowest (53.04 points) (Table 7) because of a high prevalence of bursitis and soiled body (Table 8); for this criterion, farm 1 scored as “not classified,” which means that its welfare status was unacceptable. For the criterion “thermal comfort,” 33.3% of the farms were classified as “acceptable,” and 66.7% were classified as “excellent,” as can also be seen in Figure 7.

2.2.1.3. Good health

Within the principle “good health,” low scores were recorded for all farms because of low scores of the criterion “absence of pain induced by management procedures” (mean = 12.33 points). All nine farms performed castration without anesthesia, and eight farms performed tail docking. The one farm (farm 6) that did not practice the tail docking scored 46 points, whereas all the other farms scored 8 points (Table 7). All nine farms were above the “enhanced” level (over 60 points) for the criterion “absence of

injuries," and eight farms were above "enhanced" while one farm (farm 1) was "acceptable" for the criterion "absence of disease."

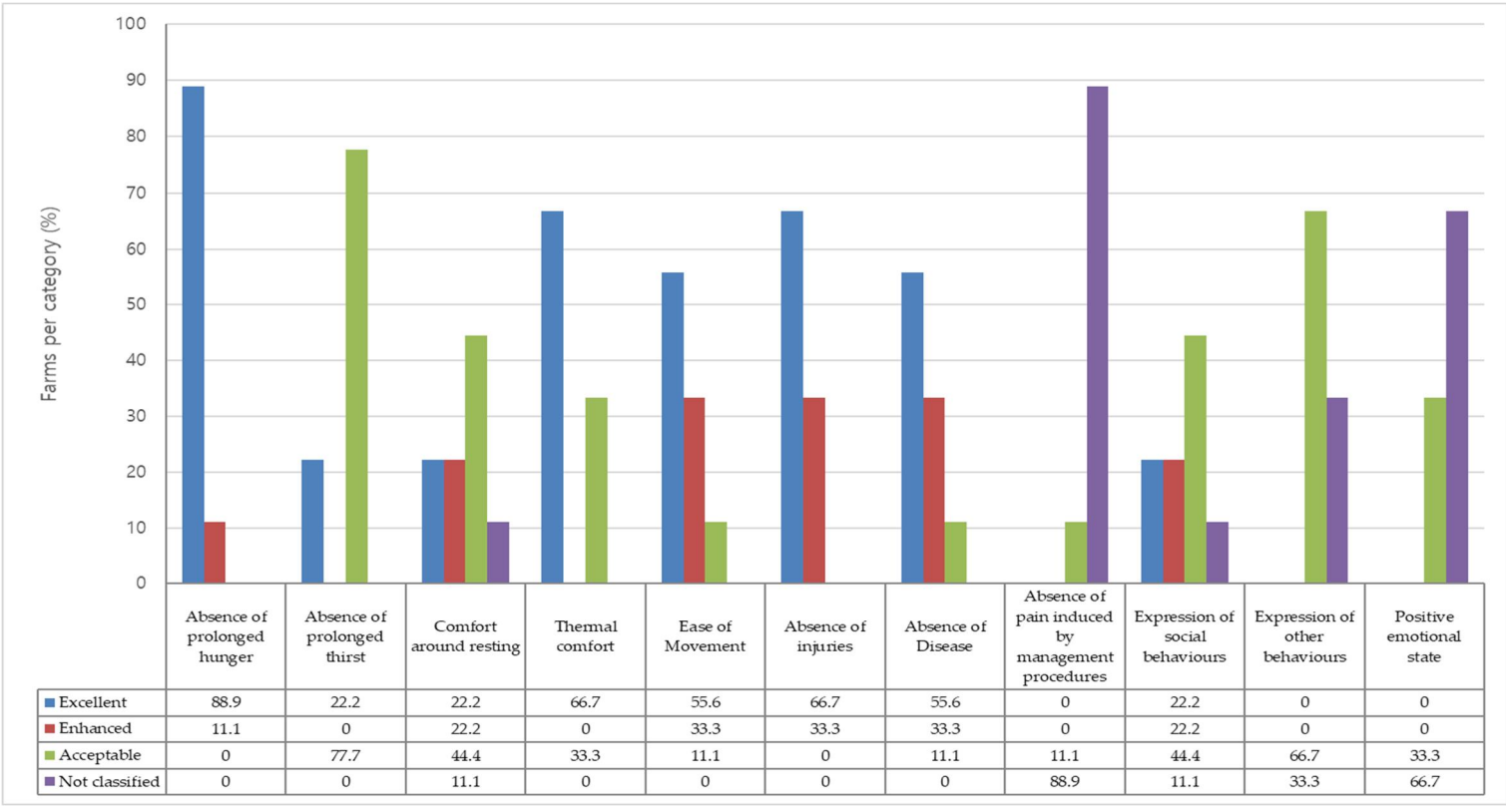
2.2.1.4. Appropriate behaviors

Among all the principles, "appropriate behaviors" scored the lowest (Table 7). Even though the mean score for the criterion "good human relationship" was 100 points, the criteria "expression of other behaviors" (mean = 19 points) and "positive emotional state" (mean = 18.89 points) were the lowest levels within the principle "appropriate behaviors" (Table 7). In terms of the criterion "expression of other behaviors." 66.7% of the farms reached the acceptable level, but 33.3% of the farms did not reach the minimum score to be classified. In terms of the criterion "positive emotional

Table 7. The result of the Welfare Quality® protocol on nine growing pig farms in South Korea

Indicator	1	2	3	4	5	6	7	8	9	Mean	SD
Overall Assessment	A[1]	A	A	E[2]	E	E	A	A	E		
Good feeding	**57.3**	**42.5**	**100**	**56.8**	**82.4**	**57.3**	**57.3**	**57.3**	**57.3**	63.13	17.20
Absence of prolonged hunger	100	100	100	90	75.5	100	100	100	100	96.17	8.43
Absence of prolonged thirst	55	40	100	55	100	55	55	55	55	63.33	21.36
Good housing	**22.4**	**73.9**	**36.7**	**81.3**	**82.7**	**65.3**	**42.7**	**47.1**	**81.2**	59.26	22.52
Comfort around resting	16.1	69.8	24.1	76.1	80.5	57.2	28.3	40.5	84.8	53.04	26.37
Thermal comfort	26	100	100	46	100	100	26	100	100	77.56	34.16
Ease of Movement	41.5	86	74.2	96.8	88.9	89.6	86.1	66.9	80	78.89	16.6
Good health	**22.5**	**31.9**	**24.8**	**35.4**	**32.2**	**54.2**	**25.6**	**38.5**	**36.1**	33.47	9.53
Absence of injuries	70.2	93.4	73	89.7	100	62.8	93.9	100	96.4	86.6	14.07
Absence of disease	52.3	84	60.6	100	84	74.1	60.6	100	100	79.5	18.66
Absence of pain induced by management procedures	8	8	8	8	8	47	8	8	8	12.33	13
Appropriate behaviors	**14.9**	**25.2**	**14**	**19.2**	**30.5**	**33.1**	**32.6**	**31.2**	**28.6**	25.48	7.58
Expression of social behaviors	26.6	49.9	28.5	14.7	55.9	100	77.6	79.7	100	59.2	32
Expression of other behaviors	7.1	22.3	5.9	23.9	27.5	22.3	28.7	22.2	11.1	19	8.7
Good human relationship	100	100	100	100	100	100	100	100	100	100	0
Positive emotional state	17.9	17.5	16	21.9	22.7	17.2	18.7	20.2	17.9	18.89	2.3

[1] Acceptable, [2] Enhanced



	Absence of prolonged hunger	Absence of prolonged thirst	Comfort around resting	Thermal comfort	Ease of Movement	Absence of injuries	Absence of Disease	Absence of pain induced by management procedures	Expression of social behaviours	Expression of other behaviours	Positive emotional state
Excellent	88.9	22.2	22.2	66.7	55.6	66.7	55.6	0	22.2	0	0
Enhanced	11.1	0	22.2	0	33.3	33.3	33.3	0	22.2	0	0
Acceptable	0	77.7	44.4	33.3	11.1	0	11.1	11.1	44.4	66.7	33.3
Not classified	0	0	11.1	0	0	0	0	88.9	11.1	33.3	66.7

Figure 8. Percentage of farms per category in the criteria of the Welfare Quality® protocol. Good human-animal relationship is not shown in the graph since 100% of the farms classified as excellent category.

Table 8. The results of the indicators of the Welfare Quality® protocol on nine pig farms

Indicators of the Welfare Quality® protocol	1	2	3	4	5	6	7	8	9	Mean	Min	Max	SD
% Lean pigs	0	1.3	0	1.4	3.8	0.0	0.0	0	0	0.73	0	3.8	1.30
No. of pigs/pen	150	13	18	30	10	30	40	40	60	43.44	10	150	42.88
Average weight	60	25.0	60.0	45.0	45.0	50.0	40.0	40.0	45.0	45.56	25	60	10.74
Floor area	63.0	5.8	13.7	54.0	9.5	33.6	28.5	17.5	39.2	29.42	5.8	63	19.97
Pigs/drinking	15	13	4.5	15	5	6	6.7	20	12	10.80	4.5	15	5.47
Number of drinking places	10	1	4	2	2	5	6	2	5	4.11	10	1	2.80
Fonctionning of drinkers	O	O	2	O	2	2	2	O	O	2.00	0	2	0.00
Cleanliness of drinkers	0	0	0	0	0	0	0	0	0	0.00	0	0	0.00
% Pigs with bursae score 0	82.7	69.3	79.2	86.5	77.1	43.2	61.2	80.1	96.7	75.12	43.2	96.7	15.57
% Pigs with bursae score 1	17.3	24.0	18.1	10.6	21.4	52.7	38.8	13.7	2.7	22.14	2.7	52.7	15.16
% Pigs with bursae score 2	0.0	6.7	2.8	2.8	1.5	4.1	0.0	6.2	0.7	2.74	0	6.7	2.49
% Pigs with manure score 0	0.0	83.3	9.0	82.3	96.2	89.2	24.2	66.4	86.7	59.71	0	96.2	37.80
% Pigs with manure score 1	36.7	16.7	45.8	14.9	3.8	10.1	37.0	5.5	12.7	20.35	3.8	45.8	15.38
% Pigs with manure score 2	63.3	0.0	45.1	2.8	0.0	0.7	38.8	28.1	0.7	19.95	0	63.3	24.42
Shivering	2	0	0	1	0	0	2	0	0	0.56	0	2	0.88
Panting	0	0	0	0	0	0	0	0	0	0.00	0	0	0.00
Huddling	0	0	0	0	0	0	0	0	0	0.00	0	0	0.00
% Animals affected with lameness score 1	6.7	1.3	4.2	1.4	0.0	1.4	1.2	0.0	0.7	1.87	0	6.7	2.18
% Animals affected with lameness score 2	0.0	0.0	0.7	0.0	0.0	0.7	0.0	0.0	0.0	0.15	0	0.7	0.30
% Pigs with wounds scored 1	4.7	0.7	1.4	6.4	0.0	0.7	0.6	0.0	0.0	1.60	0	4.7	2.31
% Pigs with wounds scored 2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.07	0	0.7	0.22
% Pigs with tail severely bitten	0	0.7	0	0	0	10.8	0	0	0	1.28	0	10.8	3.58
Frequency of coughing per pig per 5 min	1.52	0	0	1.3	1.3	1.2	0.7	0.8	0.7	0.84	0	1.52	0.56
Frequency of sneezing per pig per 5 min	1.84	0	1.75	0.60	1.00	2.18	1.40	1.10	1.30	1.24	0	2.18	0.67
% Pigs with labored breathing	0	0	0	0	1	0	0	0	0	0.11	0	1	0.33
% Pigs with thirsted snout	0	0	0	0	0	0	0	0	0	0.00	0	0	0.00
% Pigs with rectal prolapse	0	0	0	0	0	0	0	0	0	0.00	0	0	0.00
Aspect of manure in the pen	2	0	2	1	0	0	2	0	1	0.89	0	2	0.93
% Pigs with more than 10% abnormal skin	0	0	0	0	2	0.68	0	0	0	0.30	0	2	0.68
% Pigs with hernia score 1	6	2	4	1.42	3.33	0.68	2.42	0	0	2.21	0	6	1.99
% Pigs with hernia score 2	0	0.67	0	0	0	0	0	0	0	0.07	0	0.67	0.22

% Pigs dead on the farm during the last 12 months	0.5	1	0.5	1	1	6	1	1	1	1.44	0.5	6	1.72
Castration	2	2	2	2	2	2	2	2	2	2.00	2	2	0.00
Tail-docking	2	2	2	2	2	0	2	2	2	1.78	0	2	0.67
% Sample points with social behavior out of sample points when pigs were active	1.4	3.2	6.0	2.3	3.6	1.2	2.7	9.1	0.3	3.32	0.3	9.1	2.74
% Sample points with negative social behavior out of sample points when pigs were active	1.0	1.1	4.1	2.0	1.0	0.0	0.3	0.9	0.0	1.15	0	4.1	1.28
% Sample points when exploration of pen features was observed out of sample points	6.7	23.5	5.5	25.0	30.4	23.6	32.1	23.4	10.8	20.11	5.5	32.1	9.94
% Sample points when exploration of enrichment material was observed out of sample point	0.0	0.0	0.0	0.3	0	0	0	0.0	0.0	0.03	0	0	0.08
% Pens with panic score 2	0	0	0	0	0	0	0	0	0	0.00	0	0	0.00
Tendency to be active	4.9	7	7.1	9.6	9.4	4.6	7.8	6.9	7.2	7.17	4.6	9.6	1.70
Tendency to be relaxed	5.2	5.3	1.2	9	9.7	6.2	4.3	5.3	2.4	5.40	1.2	9.7	2.74
Tendency to be fearful	2.3	0.2	1.2	0.2	0.8	0.5	0.5	0.2	0.8	0.74	0.2	2.3	0.67
Tendency to be agitated	2	1.6	7.3	0.1	0.2	0.5	4.8	0.2	1.4	2.01	0.1	7.3	2.47
Tendency to be calm	5.6	4.3	0.9	7.6	9.6	7	1.7	4.3	2.9	4.88	0.9	9.6	2.86
Tendency to be content	2.4	4.3	1.2	7.8	10.1	3.1	5.5	7	3.4	4.98	1.2	10.1	2.87
Tendency to be tense	1	0.9	4.9	0.1	0	0	1.3	0.2	1	1.04	0	4.9	1.53
Tendency to be enjoying	0.5	4.6	0.7	8.7	10.1	2.6	4	6.5	1.4	4.34	0.5	10.1	3.48
Tendency to be frustrated	1.8	1.8	6.9	0.1	0.1	0.2	3.5	0.3	2.4	1.90	0.1	6.9	2.23
Tendency to be bored	5.2	2.8	2.3	0	0.3	6.2	0.9	3.3	4.9	2.88	0	6.2	2.23
Tendency to be playful	2.5	6.2	4.1	7.4	8.1	0.6	4.7	6.5	1.5	4.62	0.6	8.1	2.66
Tendency to be positively occupied	2.5	2.6	3.6	9.1	8.9	1.8	4.2	6.6	3.1	4.71	2.5	9.1	2.79
Tendency to be listless	8.9	2.2	2.1	0.5	0.1	8.8	0.8	0.2	1.1	2.74	0.1	8.9	3.54
Tendency to be lively	3.7	7	5.5	8.9	9.6	1	6.3	6.4	4.9	5.92	1	9.6	2.61
Tendency to be indifferent	1.8	4.3	2.5	0.2	0.1	1.7	1.3	0.5	0.9	1.48	0.1	4.3	1.32
Tendency to be irritable	1.9	2.1	8.7	0.1	0	0.8	1.7	0.7	0.8	1.87	0.1	8.7	2.67
Tendency to be aimless	1	0.8	2.8	0.3	0.2	3.3	1.6	0.4	1	1.27	0.2	3.3	1.11
Tendency to be happy	3.3	4.3	1	8	10.2	3	5.5	7.4	3.1	5.09	1	10.2	2.94
Tendency to be distressed	1.7	1.2	7.5	0.1	0	1.3	1.1	0	2	1.66	0	7.5	2.31
Tendency to be sociable	2.5	6.9	1.3	8.7	9.3	2.4	4	5.2	3.6	4.88	1.3	9.3	2.86

State," 33.3% of the farms were ranked as the acceptable level; however, 66.7% of the farms did not reach the minimum score for acceptability (Figure 8).

2.2.2. Environment-based parameters

2.2.2.1. The results of the environment-based parameters

The temperature, relative humidity, air speed, and particulate matter concentration results are presented in Table 9. Temperature, relative humidity, air speed and particulate matter concentrate ranged from 9.15°C to 26.29°C (mean ± SD = 18.62°C ± 5.76°C), 39.61% to 100% (mean ± SD = 75.24% ± 21.04%), 0 to 0.04 m/s (mean ± SD = 0.021 m/s ± 0.03 m/s), 192.33 to 1397.25 $\mu g/m^3$ (mean ± SD = 696.34 ± 466.2 $\mu g/m^3$) for PM_{10}, 34.83 to 233.02 $\mu g/m^3$ (mean ± SD = 94.52 ± 77.11 $\mu g/m^3$) for $PM_{2.5}$, 9.2 to 94.22 $\mu g/m^3$ (mean ± SD = 35.45 ± 28.9 $\mu g/m^3$) for PM_1 and 226.75 to 3997.17 $\mu g/m^3$ (mean ± SD = 1385.93 ± 1193.52 $\mu g/m^3$) for TSP across the nine pig farms, respectively. The concentrations of total airborne bacteria, airborne total coliform, and airborne total *e. coli* ranged from 3.33 to 4.36 (mean ± SD = 4.08 ± 0.29 CFU/m^3), 1.87 to 3.82 (mean ± SD = 2.89 ± 0.66 CFU/m^3), and 0 to 3.49 CFU/m^3 (mean ± SD = 2.28 ± 1.05 CFU/m^3) across the nine pig farms, respectively (Table 10). The concentrations of hydrogen sulfide, ammonia, and carbon dioxide ranged from 0 to 1.23 (mean ± SD = 0.41 ± 0.42 ppm), 3.69 to 68.17 (mean ± SD = 30.05 ± 26.21 ppm), 955 to 5583.75

Table 9. The results of the microclimate parameters and the concentration of Particulate matters in nine pig farms

ITEM	1	2	3	4	5	6	7	8	9	AVE	SD
TEM [1]	16.45	16.55	19.28	9.15	11.71	25.21	26.29	21.06	21.83	18.62	5.76
RH [2]	100.00	48.26	92.02	75.30	39.61	67.80	73.63	81.93	98.60	75.24	21.04
AS [3]	0.00	0.00	0.00	0.08	0.00	0.02	0.02	0.04	0.02	0.021	0.03
PM [4] $_{10}$	1249.47	207.87	214.03	297.80	825.82	1216.65	192.33	1397.25	665.88	696.34	496.20
PM $_{2.5}$	209.22	42.75	105.53	36.75	34.83	45.65	39.18	103.73	233.02	94.52	77.11
PM $_{1}$	16.72	28.68	49.08	19.75	10.23	9.20	24.72	66.45	94.22	35.45	28.90
TSP[5]	1292.68	701.57	226.75	590.65	1892.20	2307.00	444.58	3997.17	1020.77	1385.93	1193.52

[1] Temperature (˚C), [2] Relative Humidity (%), [3] Air Speed (m/s), [4] Particulate Matters $\mu g/m^3$), [5] Total Suspended Particulate Matter ($\mu g/m^3$)

Table 10. Concentration of Airborne bacteria in nine pig farms

Airborne Bacteria	1	2	3	4	5	6	7	8	9	AVE	SD
TAB [1]	3.33	4.24	3.99	4.36	4.02	4.15	4.24	4.14	4.24	4.08	0.30
AC [2]	2.84	3.56	1.87	2.69	3.39	3.34	1.92	3.82	2.55	2.89	0.70
AE [3]	2.62	3.27	0.00	1.29	2.98	2.84	1.61	3.49	2.44	2.28	1.12

[1] Total Airborne Bacteria Count (CFU/m^3), [2] Airborne Total Coliform (CFU/m^3), [3] Airborne Total *E. coli* (CFU/m^3)

Table 11. Concentration of CO_2, NH_3, H_2S in nine pig farms (ppm)

Gases	1	2	3	4	5	6	7	8	9	AVE	SD
H_2S	1.23	0	0.75	0.27	0.16	0.74	0.45	0	0.13	0.41	0.42
NH_3	41.67	9.60	57.6	11.83	3.69	59.07	11.3	7.5	68.17	30.05	26.21
CO_2	1400	2686.24	5583.75	955.00	1014.13	4766.67	4040	2816.67	3243.33	2945.09	1648.04

Table 12. The correlation between environment-based parameters used on nine growing pig farms

Item	TEM[1]	RH[2]	AS[3]	PM^4_{10}	$PM_{2.5}$	PM_1	TSP[5]	TAB[6]	TC[7]	TE[8]	H_2S	NH_3	CO_2
TEM	1.000												
RH	0.067	1.000											
AS	0.375	0.111	1.000										
PM_{10}	-0.133	0.283	0.230	1.000									
$PM_{2.5}$	0.333	0.833**	0.009	0.317	1.000								
PM_1	0.250	0.467	0.383	-0.183	0.517	1.000							
TSP	0.033	-0.133	0.315	0.867**	0.067	-0.250	1.000						
TAB	0.119	-0.288	0.485	-0.509	-0.356	0.186	-0.271	1.000					
AC	-0.233	-0.433	0.085	0.533	-0.233	-0.167	0.783*	-0.068	1.000				
AE	0.000	-0.400	0.111	0.500	-0.100	-0.067	0.800**	-0.136	0.950**	1.000			
H_2S	-0.276	-0.444	-0.581	-0.084	-0.310	-0.611	0.134	-0.034	0.368	0.368	1.000		
NH_3	0.067	0.000	-0.204	0.000	0.233	-0.017	0.133	-0.186	0.000	0.200	0.477	1.000	
CO_2	-0.183	0.183	-0.230	0.767*	0.350	-0.367	0.667*	-0.695*	0.317	0.367	0.276	0.517	1.000

[1] Temperature (˚C), [2] Relative Humidity (%), [3] Air Speed (m/s), [4] Particulate Matters $\mu g/m^3$), [5] Total Suspended Particulate Matter $\mu g/m^3$), [6] Total Airborne Bacteria Count (CFU/m^3), [7] Airborne Total Coliform (CFU/m^3), [8] Airborne Total *E. coli* (CFU/m^3)

ppm (mean ± SD = 2945.09 ± 1648.04 ppm) across the nine pig farms, respectively (Table 11).

2.2.2.2. Correlation between environment-based parameters

We also found some relationship between environment-based parameters, and they are shown in Table 12. PM_{10} had positive correlation with temperature and relative humidity (p<0.001). TSP was positively correlated with PM_{10}, airborne total coliform, and airborne total *e. coli* (p<0.05). As the airborne total coliform increased, the airborne total *e. coli* also increased. (p<0.001).

2.2.3. Correlation between animal- and environment-based parameters

Table 13 shows the correlation between principle assessment level of the Welfare Quality® protocol and environment-based parameters. Principle "good housing" had a negative correlation with airborne total *e-coli* and "good health" is positively correlated with air speed (P < 0.05). Correlations between 12 criteria assessment level of the Welfare Quality® protocol and environment-based parameters are shown in Table 14. Positive correlations were observed between "absence of prolonged hunger" and CO_2 (P < 0.05). The criterion "absence of injuries" had a positive correlation with air speed and a negative correlation with H_2S (P < 0.05). "Absence of Disease" had a positive correlation with air speed (P < 0.05) and a negative correlation with

H_2S ($P < 0.01$). “Positive emotional state” had positive correlations with air speed and airborne total coliform, a negative correlation with “CO_2” ($P < 0.05$).

The significant correlation between the scores of indicators of the Welfare Quality® protocol and environment-based parameters is shown in Table 15. Table 15 is shown only when there is a correlation between animal- and environment-based parameters, and the overall correlation is shown in Appendix 2. Temperature had a negative correlation with “abnormal skin” and relative humidity had a negative correlation with “coughing.” Air speed in the pig house negatively effects on “manure score 1,” “lameness score 1,” “hernia score 1,” and negative emotional states; “listless,” “indifferent,” and “irritable” ($p<0.05$). PM did not have effects on any indicator of this protocol. Total airborne bacteria count had a positive correlation with “coughing” and a negative correlation with negative emotional states; “indifferent” and “irritable” ($p<0.05$). Airborne total coliform had a positive effect on “sneezing” and airborne total *e. coli* had a positive effect on “manure score 2” and “sneezing” ($p<0.05$). It was analyzed that the concentration of gases in the pig house had significant influence on pig’s emotional states. The concentration of ammonia had a negative correlation with the positive emotional states: “content,” “enjoying,” “sociable,” “playful,” “lively,” and “happy,” and had positive correlations with the negative emotional states: “aimless” and “distressed” ($p<0.05$). The concentration of carbon dioxide had negative correlations with the positive emotional states: “calm,” “sociable,” “playful,” and “happy” and had a positive correlation with the negative emotional state: “aimless,” and the concentration of hydrogen sulfide also had a positive correlation with the negative emotional state: “fearful” ($p<0.05$).

Table 13. Correlation between four principle assessment level of the Welfare Quality® protocol and environment-based parameters

Items	Good feeding	Good housing	Good health	Appropriate behaviors
TEM[1]	-0.584	0.050	0.050	-0.033
RH[2]	0.201	0.133	-0.100	-0.450
AS[3]	0.000	0.519	0.672*	0.451
PM^4_{10}	0.529	-0.383	0.217	0.400
$PM_{2.5}$	0.018	-0.233	-0.233	-0.400
PM_1	-0.347	0.217	0.217	-0.267
TSP[5]	0.420	-0.500	0.267	0.533
TAB[6]	0.037	0.475	0.034	0.051
AC[7]	0.402	-0.650	0.050	0.317
AE[8]	0.237	-0.700*	0.100	0.250
H_2S	0.422	-0.586	-0.502	-0.293
NH_3	0.073	-0.250	0.083	-0.167
CO_2	0.420	-0.517	0.050	0.233

[1] Temperature (˚C), [2] Relative Humidity (%), [3] Air Speed (m/s), [4] Particulate Matter $\mu g/m^3$), [5] Total Suspended Particulate Matter $\mu g/m^3$), [6] Total Airborne Bacteria Count (CFU/m^3), [7] Airborne Total Coliform (CFU/m^3), [8] Airborne Total *E. coli* (CFU/m^3); *P < 0.05 (2-tailed), **P < 0.001 (2-tailed)

Table 14. Correlation between 12 criteria assessment level of the Welfare Quality® protocol and environment-based parameters

Items	APH	APT	CAR	TC	EM	AI	AD	APMP	ESB	EOB	PES
Tem[1]	0.091	-0.478	0.117	-0.478	0.083	0.192	0.402	-0.411	-0.126	0.209	0.293
RH[2]	0.091	0.179	0.250	0.568	-0.333	0.427	0.359	-0.548	-0.008	-0.418	-0.184
AS[3]	-0.315	0.092	0.570	0.198	0.153	0.731*	0.790*	-0.140	0.462	0.282	0.675*
PM^4_{10}	0.479	0.299	-0.300	0.378	-0.317	0.259	-0.051	0.137	0.577	-0.176	-0.259
$PM_{2.5}$	0.525	-0.139	-0.017	0.239	-0.583	0.268	0.154	-0.548	0.084	-0.536	-0.360
PM_1	0.114	-0.378	0.367	0.299	-0.467	0.402	0.607	-0.411	0.075	-0.427	0.142
TSP[5]	0.502	0.199	-0.417	0.010	-0.283	0.100	-0.137	0.274	0.586	-0.100	-0.126
TAB[6]	-0.650	0.213	0.441	-0.344	0.186	0.383	0.235	-0.279	-0.085	0.349	0.783*
AC[7]	0.388	0.199	-0.650	-0.189	-0.483	-0.109	-0.376	0.274	0.268	-0.251	-0.042
AE[8]	0.525	0.040	-0.650	-0.259	-0.500	-0.209	-0.291	0.274	0.259	-0.351	-0.134
H_2S	0.115	0.405	-0.636	-0.500	-0.075	-0.752*	-0.803**	0.275	-0.345	-0.273	-0.370
NH_3	0.456	-0.020	-0.050	0.000	-0.050	-0.611	-0.162	0.411	0.209	-0.527	-0.644
CO_2	0.707*	0.149	-0.367	0.279	-0.200	-0.276	-0.359	0.411	0.519	-0.335	-0.745*

[1] Temperature (˚C), [2] Relative Humidity (%), [3] Air Speed (m/s), [4] Particulate Matter $\mu g/m^3$), [5] Total Suspended Particulate Matter ($\mu g/m^3$), [6] Total Airborne Bacteria Count (CFU/m^3), [7] Airborne Total Coliform (CFU/m^3), [8] Airborne Total *E. coli* (CFU/m^3); APH absence of prolonged hunger, APT absence of prolonged thirst, CAR comfort around resting, TC thermal comfort, EM ease of movement, AI absence of injuries, AD absence of disease, APMP absence of pain induced by management procedures, ESB expression of social behaviors, EOB expression of other behaviors, PES positive emotional state; *P < 0.05 (2-tailed), **P < 0.001 (2-tailed)

Table 15. Correlation between the results of the indicators of the Welfare Quality® protocol and environment-based parameter

Principles	Indicators	TEM [1]	RH [2]	AS [3]	TAB [4]	AC [5]	AE [6]	H_2S	NH_3	CO_2
Good housing	Manure score 1			-0.681*						
	Manure score 2						0.689*			
Good health	Lameness score1			-0.781*				0.789*		
	Lameness score 2									0.725*
	Coughing		-0.692*		0.730*					
	Sneezing					0.683*	0.700*	0.778*		
	Abnormal skin	-0.730*								
	Hernia score 1			-0.718*						
Appropriate behaviors	Positive social behavior								-0.717*	
	Fearful							0.687*		
	Calm									-0.728*
	Content								-0.733*	
	Enjoying								-0.750*	
	Sociable								-0.767*	-0.800**
	Playful								-0.867**	-0.667*
	Listless			-0.766*						
	Lively								-0.800**	
	Indifferent			-0.843**	-0.746*					
	Irritable			-0.795*	-0.698*					
	Aimless								*0.711**	0.879**
	Happy								-0.817**	-0.783*
	Distressed								0.845**	

[1] Temperature (˚C), [2] Relative Humidity (%), [3] Air Speed (m/s), [4] Total Airborne Bacteria Count (CFU/m^3), [5] Airborne Total Coliform (CFU/m^3), [6] Airborne Total *E. coli* (CFU/m^3); *P < 0.05 (2-tailed), **P < 0.001 (2-tailed)

2.2.4. The comparison of the results of the Welfare Quality® protocol on growing pigs between South Korea and the European nations

2.2.4.1. Overall assessment

Figure 9 shows the distribution (%) of results for welfare assessment on growing pig farms assessed in South Korea and the European nations using the Welfare Quality® protocol. In the aspect of the "overall assessment," none of the farms assessed in South Korea and the European nations were classified as "not classified," 22% of the farms in the European nations were classified as "excellent," compared to 0% of the ones in South Korea.

2.2.4.2. Principles

The distribution of farms assessed on principle "good feeding" in South Korea and the European nations was generally similar, 22.2 and 38% of farms were classified as "excellent," 77.8 and 60% of farms as "acceptable," respectively. In addition, none of the farms were classified as "not classified" in both regions. Therefore, the differences between the average score of principle "good feeding" between South Korea and the European nations were small at 0.94 point (Figure 10). In the aspect of principle "good housing," the distribution of the farms classified as "acceptable" in South Korea and the European nations was similar, with 44.4% and 41%, and no farms were classified as "not classified." The farms with "excellent" category in South Korea was more than those in the European

nations (33.3% and 18%), but the farms of “enhanced” category in South Korea was less than those in the European nations (22.2% and 42%). In the principles “good health” and “appropriate behaviors” aspects, the farms categorized as “excellent” and “enhanced” were 0% in South Korea, whereas those in the European nations were 35% in the principle “good health” and 29% in the principle “appropriate behaviors,” respectively. The farms categorized as “not classified” in principle “appropriate behaviors” were 33.3 percent in South Korea, higher than 0 percent of the European nations. In addition, the difference between the average score of the two principles in South Korea and the European nations was 16.88 and 24.99 point, respectively (figure 10). In fact, the difference between the average scores of these two principles was greater than that of the principle “good feed” with 0.94 point and “good housing” with 6.05 point, respectively (figure 10).

2.2.4.3. Criteria

The distribution of farms and the average scores in criterion “absence of prolonged hunger” was similar between South Korea and the European nations, with the highest score among 12 criteria. In this criterion, 89% and 95% of the farms in South Korea and the European nations were classified as “excellent” categories (figure 9). In relation to the “absence of prolonged thirst” criterion, the average scores in South Korea and the European nations were 63.33 and 63.28 points, with 0.05 points higher in South Korea than in the European nations (figure 10). In addition, 8% of the farms in the European nations were classified as “not classified” while none

of the farms were classified as “not classified” in South Korea in this criterion (figure 9). The average scores of the European nations were 14.67 and 15.25

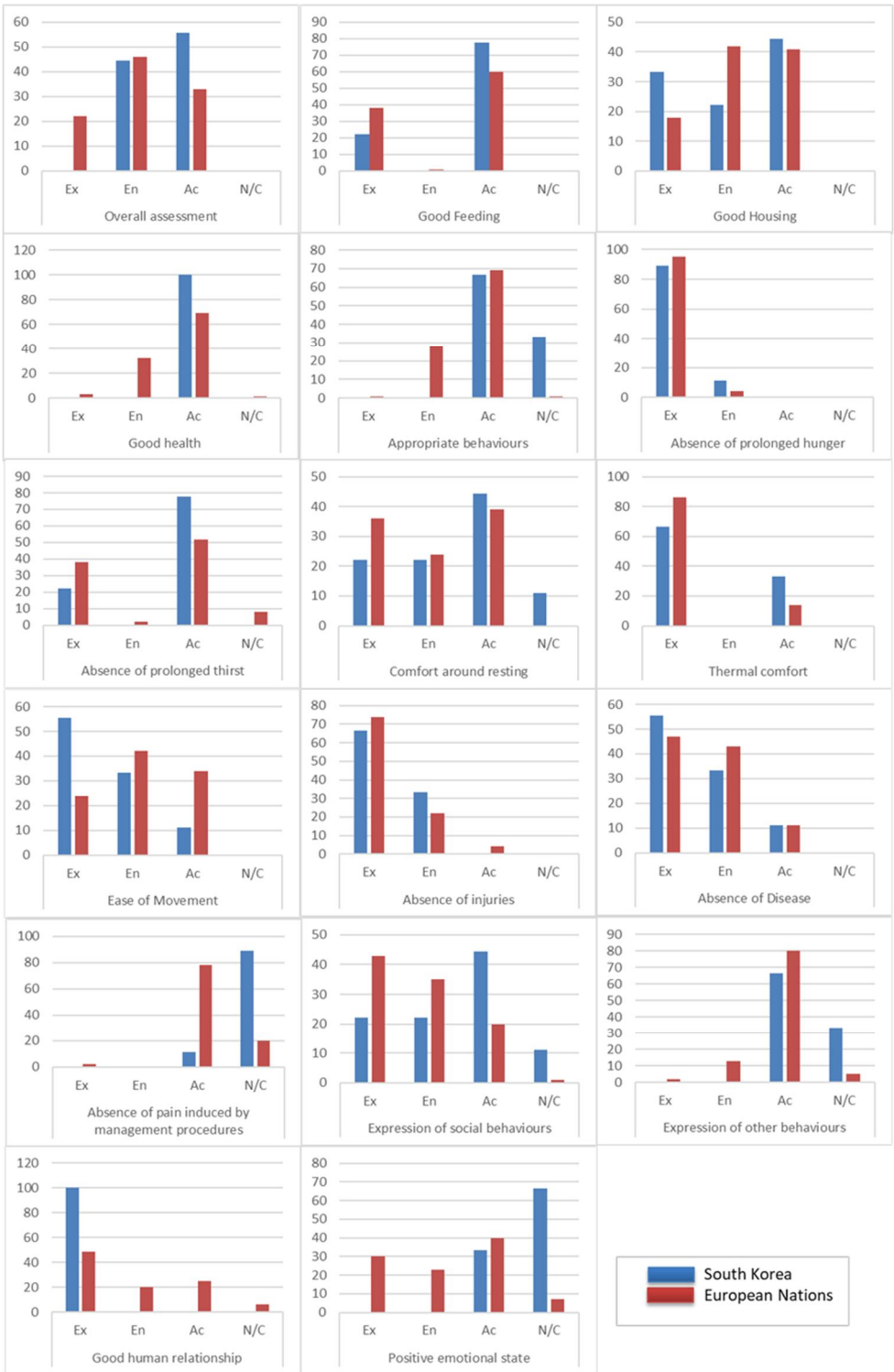
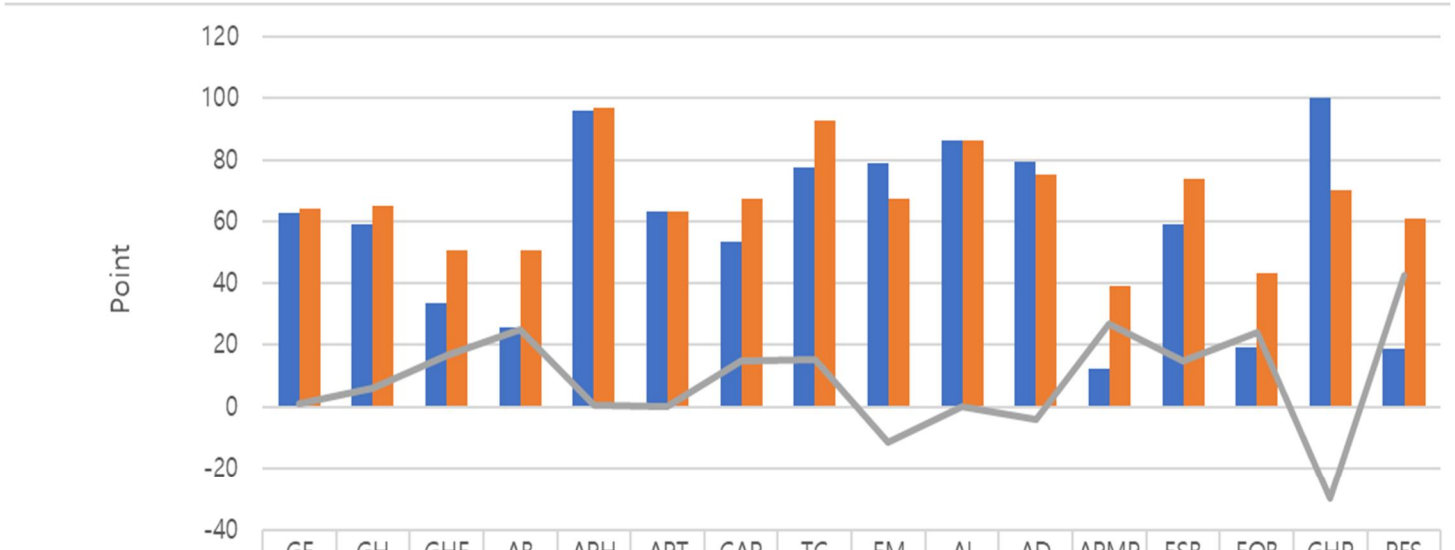


Figure 9. The comparison of the results of the Welfare Quality® protocol on growing pigs between South Korea and the European nations



	GF	GH	GHE	AB	APH	APT	CAR	TC	EM	AI	AD	APMP	ESB	EOB	GHR	PES
South Korea	63.13	59.26	33.47	25.48	96.17	63.33	53.04	77.56	78.89	86.6	79.5	12.33	59.2	19	100	18.89
European Nations	64.07	65.31	50.35	50.47	96.78	63.28	67.71	92.81	67.42	86.55	75.44	39.19	73.87	43.07	70.35	61.25
Difference	0.94	6.05	16.88	24.99	0.61	-0.05	14.67	15.25	-11.47	-0.05	-4.06	26.86	14.67	24.07	-29.65	42.36

Figure 10. The differences of average scores on the results of the Welfare Quality® protocol on growing pigs between South Korea and the European nations. GF good feeding, GH good housing, GHE good health, AB appropriate behaviors, APH absence of prolonged hunger, APT absence of prolonged thirst, CAR comfort around resting, TC thermal comfort, EM ease of movement, AI absence of injuries, AD absence of disease, APMP absence of pain induced by management procedures, ESB expression of social behaviors, EOB expression of other behaviors, GHR good human relationship, PES positive emotional state

points higher than those of South Korea in the criteria “comfort around rest” and “thermal comfort” (Figure 10). The average score of the criterion “easy of movement” in South Korea was 11.47 points higher than that of the European nations. In addition, 56% of the farms in South Korea and 24% in the European nations were classified as “excellent” categories in this criterion, and South Korea had bigger space allowance for growing pigs. In relation to the criteria “absence of injuries” and “absence of disease,” the average scores in South Korea were 0.05 and 4.06 point, higher than those in the European nations, respectively (figure 10). In the section of criterion “absence of pain induced by management procedures,” the average scores of both regions were the lowest among 12 criteria with 12.33 points for South Korea and 39.19 points for the European nations, respectively (figure 10). In addition, the farms classified as “not classified” in this criterion was 88.9% in South Korea, which had big difference with 20% of the European nations (figure 9).

In relation to the “expression of other behaviors,” the farms in South Korea and the European nations scored 18.89 points and 61.25 points on average, with 24.07 points difference (figure 10). In addition, this criterion was the second weakness of the welfare quality in the European nations, following the criterion “absence of pain induced by management procedures,” and none of the farms were classified as “excellent” and “enhanced” categories (figure9). In the criterion “good human relationship” aspect, 100% of the farms in South Korea were classified as “excellent,” while 49% for “excellent,” 20% for “enhanced,” 25% for “acceptable,” and 6% for “not classified” in the European nations, respectively (figure 9). All the farms in

South Korea scored 100 points in this criterion, 24.07 points higher from the average score in the European nations (figure 10). In relation to the criterion “positive emotional state,” the farms in South Korea and the European nations scored 18.89 points and 61.25 points on average, with the biggest difference among the 12 criteria (Figure 10). In fact, this criterion, which was second weakness of the welfare quality in South Korea showed the distribution with 0% for “excellent” and “enhanced,” 33.3% for “acceptable” and 66.7% for “not classified,” while the distribution of the European nation was 30% for “excellent,” 23% for “enhanced,” 40% for “acceptable,” and 7% for “not classified,” respectively (figure 9).

Chapter 3. Discussion & Summary

3.1. Conclusions

This study is a first step in evaluating and developing a new growing pig welfare assessment protocol that combines animal- and environment-based parameters. Environment-based parameters can help to assess welfare status easily whenever animal-based parameters are difficult.

Our results indicate that the welfare situation in South Korea is above "acceptable" level and none of the assessed farms in South Korea are "not classified" according to the Welfare Quality® protocol. Among the 12 criteria, the serious animal welfare problems on the assessed farms were related to 1) the criterion "absence of pain induced by management procedures," and 2) the criteria "positive emotional state" and "expression of other behaviors." To improve the criterion "absence of pain induced by management procedures," legal regulations on routine tail docking or the use of anesthetics during tail docking and castration are required; however, if tail docking is performed, the score for the criterion "absence of injuries" could be lowered, so environmental improvements such as decreasing the stocking density or providing enrichment are essential. In addition, this study indicated that that animal welfare, particularly the criterion "positive emotional states," can be improved by controlling air quality such as ammonia, hydrogen sulfide, and carbon dioxide in the correlation between welfare assessment results using animal- and environment-based parameters.

As the results of the Welfare Quality® protocol on growing pigs, the European nations and South Korea showed different patterns. In the principle aspect, the "good feeding" and "good housing" in South Korea is similar to

the European nations, but “good health” and “appropriate behaviors” in South Korea is worse than those of the European nations. The main reason of the low score with those principles in South Korea is the low scores of the criteria “absence of pain induced by management procedures,” “expression of other behaviors,” and “positive emotional state.” To improve the welfare status in these criteria, it is necessary to study the systems and procedures related to farm animals' welfare improvement in Europe, to expand the related research in South Korea and promote efficient system improvement such as expanding incentives for animal welfare farms, so that they can be applied to the South Korean situation.

3.2. Discussion

3.2.1. Animal-based parameters

3.2.1.1. Good feeding

The percentage of lean pigs is the only parameter for the criterion “absence of prolonged hunger” in the Welfare Quality® protocol. This often results in low assessment sensitivity for body condition when using the Welfare Quality® protocol; however, pigs in intensive farming systems are generally fed ad lithium to grow quickly (80), so the prevalence of poor body condition is usually very low. The results of this study (0.73%) were higher than those (0.4%) of Temple et al. (81), who conducted assessments on 91 growing pig farms from 2007 to 2009 in France and Spain, and those (0.2%) of Meyer-Hamme et al. (82), who conducted assessments on 60 fattening

pig farms from 2013 to 2014 in Germany This seems to be because pigs assessed in the present study are younger than those assessed in the two studies. The criterion “absence of thirst” scored low since many farms had water nipples that did not function properly; this may be related to the low illuminance in the pig house, the high stocking density of the pigs, and/or the high work intensity of the farmer. In the present study, the average number of pigs per drinker was 10.8, and it ranged from 4.5 to 15 pigs per drinker. In fact, there were less than two water nipples in the pen for four out of nine farms; if one or more of these nipples don’t work properly, this would be a serious welfare problem in terms of the criterion “absence of thirst.”

3.2.1.2. Good housing

A bursa is a fluid filled sac that arises in the subcutaneous connective tissue due to the exudation of fluid from traumatized capillaries and lymphatic vessels after pressure over a bony prominence (83,84). Moderate and severe bursitis are indicators of comfort around resting; as such, this is an animal-based parameter for evaluating comfort around resting (20). In the present study, moderate bursitis was present at a prevalence of 22.14% (Table 8), which was the most prevalent animal-based indicator; however, our prevalence was lower than that which Meyer-Hamme et al. (85) and Temple et al. (81) observed on conventional pig farms (35% and 43.5%, respectively). Bursitis is highly related to the pig’s age (86), so the results of Meyer-Hamme 's study (85) of fattening pigs may be higher than those of our study on growing pigs. As pigs spend about 80% of their time lying (87, 88), the type of flooring in the pig house is very important for

their welfare, especially in terms of comfort around resting. According to many studies of the positive effects of straw on pig welfare, bedding improves the physical comfort of the hard floor (89,90). In our study, “Bursitis 0” (no evidence of bursa on the legs) was very high with sawdust flooring (farm 7 and 9) and “Bursitis 1” was higher with concrete slat flooring. According to Tuyttens (90), solid concrete flooring is a risk factor of bursitis. Mouttotou et al. (84) also found that deep bedding was the most important factor that reduced bursitis. In addition, Lyons et al. (91) found four times more bursitis with concrete and slatted floors than deep-straw floors.

The prevalence of moderately soiled bodies (20.35%) noted in the present study (Table 8) is like those reported by Temple et al. (80), who conducted assessments on 30 intensive growing pig farms in Spain, Meyer-Hamme et al. (82) (16.6 and 15.5%, respectively). In contrast, the prevalence of a severely soiled body (19.95%) in this study was much higher than the values of 3.7% and 6.2% reported by Temple et al. (81) and Meyer-Hamme et al. (82), respectively. Soiled bodies are influenced by multiple factors, including environmental factors (92) in conventional farming system (19); e.g., seasonal effects, cleanliness, and the types of flooring (85). Temple et al. (81) also found that moderately soiled body measurements appeared to be sensitive to differences between intensive farming systems. In this study, the relative humidity of the pig house was very high, which could dilute the manure on the floor, making it easy for pigs to get dirty. Moreover, two pig farms had sawdust floors in this study, but in the all-in-all-out system, the sawdust was wet and dirty, leading to worse dirtiness scores. Therefore, on farms with sawdust floors, a certain portion of sawdust should be regularly

changed (e.g., once every two weeks), and on farms with slatted concrete floors, new bedding should be provided at regular intervals.

3.2.1.3. Good health

The principle “good health” scored as the second worst principle, after the “appropriate behaviors”; the low score for the criterion “absence of pain induced by management practice” was the decisive factor. Tail docking was performed on eight farms (except farm 6), and additional castration was carried out on all farms. No farms used anesthetics or analgesics when performing tail docking and castration. If regulations on the tail docking and castration of pigs were to be established in South Korea, scores for the principle “good health” could rise further. Nonetheless, farm 6, without tail docking, had the lowest score for the criterion “absence of injuries.” When stocking density is high, and pigs cannot express their species-specific behaviors in barren housing environments, they bite their penmates. Therefore, providing pigs with an environment conducive to positive behavior should be a priority, even if tail docking is prohibited. The prevalence of moderately wounded pigs (1.6%) was much lower than the levels (10.5%) observed by Meyer et al. (82). In general, negative social behavior can increase body wounds. Since “wounds on the body” are more frequent as pigs get older, the results of this study that assessed growing pigs seem to be lower than the results of Meyer et al.’s study (82) that assessed fattening pigs. According to Meyer et al (82), farmers who manage the whole production cycle are specialized, whereas farmers who only raise pigs during the fattening stage are not necessarily specialized. All the farms in the

present study were relatively small, with less than 5,000 pigs, and small farms normally employ a limited number of farmers to save labor costs, so they devote relatively little time and effort to growing/fattening pigs compared to sows. In the study of Temple *et al.* (19), health data assessed in her study were not significantly different between 5 different production systems (conventional; straw bedding; intensive Iberian; extensive Mallorcan black pig; extensive Iberian). She concluded that simple environment-based parameters can be useful to evaluate farms and those are more likely to show one of these health problems. The farmers might have neglected to keep a record particularly of mortality for the criterion “absence of disease,” but it was necessary to trust the information provided by the farmers about the numbers of dead pigs. In order to trust the mortality of pigs as the Welfare Quality® protocol, it must be strictly enforced and monitored by regulations.

3.2.1.4. Appropriate behaviors

Animal behavior is a sensitive indicator of environmental changes. Changes in behavior often represent the first level of response to an environment that stresses animals. Behavior is a clear indicator of poor welfare, especially when associated with physical pain; it is the most used parameter for assessing animal pain (34). Van de Weerd and Day (93) noted that intensive farming systems are criticized for the inability of animals to perform species-specific behaviors; in the present study, the lowest score for the principle “appropriate behaviors” demonstrates this phenomenon. Behavioral assessment is more subjective than the other three principles (94),

but both psychological and physiological parameters are essential to evaluating farm animal welfare (95). In the present study, “appropriate behaviors” scored the lowest among the four principles, with three out of nine farms (farm 1, 3, and 4) scoring below “acceptable” (Table 7). The criteria “expression of other bahaviors” and “positive emotional state” also had a determining effect. Frank suggested that providing pigs in barren housing environments with enrichment in the form of straw, peat, or extra space can have a positive effect on pig behaviors. However, it is difficult to increase the space allowance or to supply bedding materials, such as straw and sawdust, in the conventional livestock industry because of production costs, incompatibility with slatted floors and liquid manure treatment systems, the additional costs for straw and labor, and concerns about increased health risks (86).

The score of “expression of other behaviors” (mean score = 19) was much lower than that of “expression of social behaviors” (mean score = 59.2 points; Table 7). This result is also supported by Petersen et al. (96), in which a decrease in exploratory behavior in intensive environments was associated with an increase in negative social behavior. In fact, behavior between penmates becomes more frequent when there is no spare space or object to explore. Pigs that fail to express the natural behavior of rooting substrate may use pen fixtures as an alternative (97). Pen fixtures may act as a temporary substitute for their nature behavior, but objects are not suitable for root-seeking and chewing (98). Therefore, penmates are often used as an alternative to express a higher level of harmful social behavior in barren environments (96,99,35). The pigs on all the farms (7 farms with slatted

concrete floors and 2 farms with sawdust floors; no addition or replacement of sawdust) evaluated in our study had nothing to play with that would encourage their natural behaviors and curiosities. According to Temple et al. (81), social behavior is also affected by the management status of the farm, as well as environmental factors. Because the growing phase is a stable period within the pig production cycle, farmers do not have to spend much time and effort caring for their pigs; in particular, as the number of growing pig houses increase, the stress between pigs in-creases because farmers do not pay attention to their growing pigs. According to Battini et al. (100), under a high workload, farmers are more likely to spend less time attending to their animals and are unable to identify important animal signals. The provision of larger space appears to be an important factor in providing comfort and enrichment to growing and fattening pigs (101). Nonetheless, producing fattening pigs in large groups has advantages for producers in terms of the efficient use of resources (e.g., space, pen divisions, feeders, and drinkers) and ease of management. Because of these advantages, producers appear to be increasingly willing to breed pigs on a large scale (i.e., maintaining groups of more than 50 pigs in a pen) (11). In the present study, as the pens got larger, more pigs were being raised in them (Table 3), such that crowding within the limited space could increase aggression and the competition (67). Velarde and Geers (92) also noted that less space can hinder behavior, and lead to social stress and reduced physiological functioning; they also found that larger pens provide more space, but some negative effects can occur as group sizes increase. For example, as the size of the group increases, the pig's social unrest and aggression increases, which can negatively affect

their health. Baxter (102) suggested that, to maintain social stability, all the pigs in the group must be able to recognize all the other pigs, and we know that pigs can recognize 20 to 30 pigs (35). This suggests that if the size of the group is larger than the number proposed by Baxter (102), there will be chronic aggression associated with permanent social instability. In the present study, 150, 40, 40, and 60 pigs were raised in a single pen on farms 2, 6, 8, and 9, respectively, which is greater than the number suggested by Baxter.

No panic response was observed on any farm in the present study. This may reflect a good relationship between the farmers and their pigs. Other factors also affect the HAR, such as genetics, growth stages, breeding materials, feeding system, stocking density, and group size (80,82,103,104). In fact, the results may be biased by the fact that pigs in a small pen cannot as easily escape from the observer as those in a large pen. In addition, the animal's curiosity can also affect their responses to humans (105). These factors can be strengthened under more intensive conditions.

QBA is an animal-based parameter in which observers judge animal behavioral expressions by integrating signals with perceived behavioral details using qualitative descriptors that reflect the emotional state of the animal (77). QBA allows scientific evidence to be applied to the expression of the animal's emotional states in specific behavioral expressions (106). In terms of the criterion "positive emotional state," six of the nine farms (66.7%) were "not classified" (Figure 7). Assessments of emotional states are highly dependent on the observers and subjective since it is difficult to evaluate the exact state of emotions in animals. While QBA is susceptible to the

contextual bias of observers, Wemelsfelder et al. (107) states that it does not undermine the basic reliability of the assessment. Wemelsfelder et al. (108) also observed that the behavioral expressions of pigs raised in an unenriched environment (with a small pen and bare concrete floor) differed from those raised in an enriched environment (half-filled with straw and containing objects like fresh branches).

3.2.2. Correlation between animal- and environment-based parameters

A few correlations between environment-based parameters and the principles and criteria of the Welfare Quality® protocol were found in the present study, but the interpretation of such relationships between these parameters was difficult. This might be because 1) the Welfare Quality® protocol was designed in a hierarchical structure to integrate several measures into overall welfare assessment (75) and 2) relatively small sample size used for the assessment. Therefore, in the present study, the relationship with environment-based parameters was analyzed at the indicator level, which is the basic stage of the Welfare Quality® protocol.

Air quality refers to the effects that the air has on the health and well-being of animals. Four (farm 1, 2, 4, and 5) out of nine pig farms had lower room temperature than the recommended temperature of growing pigs, which is around 18 to 26.7°C (109) In low temperature, pigs have poor feed conversion rates, decreased immune response. Cargill and Byrt (110) showed that the incidence of scouring increased in neonatal pigs, and the

mortality rate increased, when the temperature in the pig house was lowered. Similarly, Le Dividich (111) found that lowering the temperature every day during the first week after weaning decreased the growth rate of piglets by 10% and significantly increased post-weaning diarrhea. Scheepens et al. (112) observed increases in diarrhea, coughing, sneezing, and hemorrhagic ear lesions in pigs exposed to low temperatures. “Abnormal skin,” which is skin inflammation or discoloration, may indicate a disease localized to the skin or a systemic disease. Skin condition is an unspecified measure that can be a symptom of a various health problems, and is affected by a variety of diseases, parasites, and disorders (113). As the temperature remains below the low critical temperature in winter in the pig house, the stress on pig increases, and the animal's ability to respond to the health problems decreases (110,112). Therefore, pigs with poor ability to respond to health problems are inevitably vulnerable to skin-related diseases.

In the present study, as the relative humidity increased, the frequency of coughing significantly increased ($p<0.05$). The average humidity of the farms in this study was 75.5%, which was high because the farmer sprayed with water vapor in the pig house to prevent respiratory diseases of pigs from the dry winter environment. Even the relative humidity of farms 2 (93.4%), 3 (100%), and 9 (98%) was much higher than the recommended maximum relative humidity of 80% (114). The most common cause of coughing is a respiratory infection caused by a virus or bacteria (115). In the growing pig houses where humidity is increased due to the sprayed water vapor, the amounts of microbes deposited on the surface of

the water vapor increases, and the viability of viruses on the surface of the water vapor increases. Therefore, the contact between pigs and pathogens that cause coughing such as influenza, respiratory syncytial virus increases, and coughing transmission between pigs can be increased (116).

In winter, there was little air flow in the growing pig house because there are no fans operating in the pig house with a mechanical ventilation system, as well as in the pig house with natural ventilation system. Nonetheless, our results indicate that air speed decreased “manure score 1,” “lameness score 1,” and “hernia score 1,” significantly (Table 8). The “manure score 2” of growing pigs has positive correlation with the concentration of airborne total *e. coli* in the pig houses ($p<0.05$). So far, there have been no studies on air quality parameters that affect “manure score 1” and “manure score 2” separately. However, Temple et al. (81) indicated that “manure score 1” and “manure scorer 2” had a moderate correlation, but this correlation was not strong enough to independently analyze these indicators. According to their study (81), “manure score 2” was more sensitive to differences between production systems (intensive system vs extensive system) than “manure score 1,” and when studying the dirtiness of pigs between intensive farming systems (81), a “manure score 1” could be distinguished better than a “manure score 2.” Manure could be diluted in the growing pig houses with high relative humidity (average 75% in the present study), and the higher the air speed, the faster the manure on the floor and pig body dries. This could help reduce the prevalence of “manure score 1.” Pigs prefer to separate their lying and dunging areas. However, stocking

density in the intensive farming system is very high, forcing pigs to lie in their dunging area. In addition to its impact on pig welfare, since excrete can cause infection, pigs' dunging area should be separated from their lying area. This could be also explained by the positive correlation between severely soiled body and airborne total *e. coli* in this study. The environment-based parameters affecting each of the “manure score 1” and “manure score 2” need further research.

“Lameness” was considered a reliable indicator when pigs were individually walked out to passage. However, it is difficult to evaluate inside the pen as it was not possible under commercial conditions to get the pigs out of the pen. Therefore, moderate lameness was not considered in this Welfare Quality® protocol (81). Therefore, “lameness 1” means severely lame, minimum weight-bearing on the affected limb, and “lameness 2” means no weight-bearing on the affected limb, or not able to walk. The evaluation of “lameness” is an insensitive indicator because it is unlikely to be feasible. In addition, since hospital pens were not included in the sample in the Welfare Quality® protocol, the prevalence of “lameness” may have been low in the present study. Mismanagement of hospital pens or insufficient availability of pens may increase the prevalence of “lameness.” The type of the floor is a major factor influencing lameness and reducing the manure on the floor may help to reduce lameness of the growing pigs (117). In this study, the prevalence of “lameness 1” could also be lowered because diluted manure, a cause of slippery floors, were reduced due to airflow. Also, as the concentration of H_2S and CO_2 in the air increased, the direct cause could not

be found for the increased prevalence of “lameness.” However, the average prevalence of “lameness 2” was very low at 0.15%, and the more manure on the floor, the higher the concentrations of H_2S and CO_2, which can roughly explain this correlation. Further research is needed to elucidate the cause. In addition, air speed decreased negative emotional states; “listless,” “indifferent,” and “irritable,” significantly (Table 15). According to Vitali et al. (118), the QBA results were more positive for growing pigs in the houses equipped with a mechanical ventilation system with high ventilation performance; good indoor air velocity.

Many of the intensive pig houses are poorly managed due to the high cost and lack of expertise. In addition, open pig houses are being operated inefficiently and unsanitarily in poor economic conditions (119). As a result, airborne bacteria generated in pig buildings can adversely affect pig health, cause environmental problems such as odors, and spread of infectious diseases (120). In South Korea, there have also been studies to measure the concentration of airborne bacteria in the pig houses. A study conducted from 2008 to 2009 by Yao et al. revealed that the concentration of total airborne bacteria, airborne total coliform, and airborne total *e. coli* in the pig houses were 2.13 - 4.3, 2.08 - 2.43, and 1.36 - 3.04 CFU/m^3, respectively. Yao et al. (70) and Kim et al. (119) reported that similar concentrations of total airborne bacteria (4.04 and 4.13 CFU/m^3, respectively) were detected in the pig houses. The present study found that the concentration of airborne bacteria in growing pig house can negatively affect the pig health. Sneezing is affected by airborne total coliform and airborne total *e. coli* (p<0.05). This can

be expected because suspended microbial pathogens can cause infectious and allergic diseases in pigs. Studies have shown that the concentrations of airborne bacteria in the pig houses are higher than those in industrial, residential, or outdoor environments (120,121). The concentration of airborne bacteria can be minimized through the control of dust, humidity, and ventilation rates.

The present study found that the concentration of gases is significantly correlated with many terms of emotional state of pigs (Table 15). The concentration of ammonia decreased the pig's positive emotions of "content," "enjoying," "sociable," "playful," "lively," and "happy" and increased the negative emotions of "aimless" and "distressed." Wathes et al. (122) explained that the main air pollutants in pig houses are ammonia, carbon dioxide, particles in the air, and microorganisms. Ammonia is a highly irritating, colorless gas according to EDF (The Environmental Defense Fund) in USA, and it is estimated that about 79.5% of the nitrogen source in pig manure is vaporized into NH_3 gas (123). The accumulation of ammonia in a pig house is an indicator of ventilation failure. In addition, ammonia is used to evaluate the environment in pig houses because it can be easily analyzed on-site. Ammonia stimulates the moist body tissues, and the eyes and lungs are stimulated even at low concentrations. In case ammonia in pig house is high, it can be sensually known through symptoms of stinging eyes or congestion in pigs' eyes (124). Fortunately, ammonia has a very sharp, pungent, and distinct smell, detectable at levels as low as 5 ppm (125). Hayes et al. (126) noted that the concentrations of ammonia in growing pig

houses were 10.8± 0.06 ppm. Similarly, Kim et al. (127) found that the concentration of ammonia in growing pig houses was 12.59 ± 1.83 ppm. Based on our current study, the mean ammonia concentrations were higher than the threshold limit value, ranging from 3.69 to 68.17 ppm (128). Ammonia concentration > 20 ppm can affect the aggressiveness of pigs and are associated with stress (129). Pigs actively avoid environments with airborne ammonia concentrations at 10–20 ppm, if given the freedom to choose (130,131,132,133). Chronic exposure to ammonia at concentrations of 20 ppm during the rearing period can cause physiological problems in pigs and can also act as a source of great stress, which can have a detrimental effect on positive behavioral experiences and potentially compromise their welfare (134). In addition, chronic exposure to ammonia and dim light has been found to have detrimental effects on social behavior in pigs (129). According to the National Pork Board US (109), the concentration of ammonia should not exceed 50 ppm. In our results, the average concentration of ammonia was 30.05 ppm (Table 11), but four out of the nine farms had ammonia concentrations greater than 40 ppm.

In addition, the concentration of carbon dioxide decreased the pig's positive emotions of "calm," "sociable," "playful" and "happy" and increased the negative emotion of "aimless." In pig houses, carbon dioxide is mainly generated via the respiration of animals, and a negligible amount is also produced as a bacterial decomposition byproduct of waste (135). The mean concentration of carbon dioxide in Canadian pig farming buildings is 2,632 ppm (136), whereas the mean concentration of carbon dioxide in the present study was 2,945 ppm, ranging from 955 to 5,584 ppm. There have been

studies on the concentration of carbon dioxide used to stun pigs in slaughterhouses, but there have been no studies on carbon dioxide and the emotional state of pigs so far. A high concentration of carbon dioxide proves that the pigs raised intensively, and the ventilation is poor, so their negative behaviors and emotions in the pigs can be reinforced. The concentrations of ammonia and carbon dioxide in this study was high because the farmers did not provide ventilation in the pig houses; in the winter, the ventilation of pig farms may decrease the growth rate of pigs. Duchaine et al. (137) compared the concentrations of ammonia and carbon dioxide in terms of seasonality, noting that winter concentrations were higher than summer concentrations.

Hydrogen sulfide is a toxic gas, heavier than air, and spreads on the surface of the slurry in the pig houses, and as a result, it tends to show a high concentration mainly on the surface of manure stored in pits in pig houses (138). Since this study measured hydrogen sulfide in the air above 60 cm from the ground in the aisle, the ammonia concentration felt by pigs when lying on the pit floor will be higher than the concentration we found. Hydrogen sulfide produces a typical “rotten egg smell” even at low levels less than 1 ppm and is a major cause of headache, dizziness, and nausea. In the present study, we found that as the concentration of hydrogen sulfide increased, the negative emotional state: “fearful” increased ($p<0.05$). According to Chapin et al. (123), pigs living under conditions of 20 ppm can develop fear of light, loss of appetite and nervousness. Hydrogen sulfide measured in this study is lower than they indicated, but pigs exposed to chronically low concentrations of hydrogen sulfide for a long time may feel more sensitive to light or other objects and can be fearful with tension.

The Ministry of Environment of South Korean government has restricted the concentration of odors along the border of pig farms to reduce civil complaints, with ammonia at 1.0 ppm and hydrogen sulfide at 0.02 ppm (139); however, this is for human residents near the pig farms. Currently, there is no odor restriction system for the welfare of animals, so an animal welfare-oriented odor regulation system needs to be established in the future. To design a reasonable odor-regulating system, it will be very useful to have data on animals' behavioral response to the different concentrations of odor producing gases, reflecting the emotional state of pigs. Criterion "positive emotional state" can be improved if pigs are provided with good gas concentrations (CO_2, NH_3, H_2S).

3.2.3. Correlation between environment-based parameters

The main cause of PM has been reported as feed provided to animals and their excrement (120). The concentration of PM depends on the amount of animal activity, stocking density, feeding methods and the temperature, relative humidity, and ventilation rate of the swine building (138). The microorganisms and odorous gas components distributed in the bottom of the pig house and in the air are easily adsorbed to PM (140,141). This could explain the positive correlation between the concentration of airborne total coliform and airborne total e. coli with TSP in this study (p<0.05). Levels of generation of PM were determined on temperature (142) and relative humidity (142), respectively. In this study, PM_{10} showed a positive correlation with temperature and relative humidity (p<0.001). However, opinions among

various researchers on the epidemiologic relationship between the concentration of PM in the pig house are not in agreement (143,144). According to Dawson (145), who comprehensively reviewed these contents, the reduction of PM in the pig house is due to air dilution effects, and it is reported that temperature and relative humidity are indirect factors affecting PM by changing pig behavior and the environment inside the pig house. In general, the distribution pattern of PM in the pig house decreases as it goes from the bottom to the top (146), and the PM in a closed farming system is not suspended in the air for a long time, they settle back to the bottom by gravity unlike gaseous substances, it can also negatively affect the health and welfare of pigs. As ventilation is hardly operated in winter, a plan for the concentration of PM in the pig house should be sought.

3.2.4. The comparison of the Welfare Quality® score of growing pigs between South Korea and the European nations

3.2.4.1. Overall assessment

While 22% of the farms evaluated in the European nations were classified as “excellent,” no farms were classified as “excellent” in Korea (Figure 8). This probably reflects the fact that public concern on animal welfare in the European nations was raised earlier and along with that concern, regulations and policy development to improve farm animal welfare have been widely conducted in the last decades (21,147,148,149). Although

all farms assessed in this present study were above the minimum level of welfare “not classified” as in the European nations, this may be because the minimum welfare standard of the initial of the initial Welfare Quality® protocol was too low or the opinions of various stakeholders were reflected in the protocol (150). In fact, there are many studies that support stakeholders have different views about animal welfare, and consumers have higher welfare expectations than farmers and suppliers (151,152,153).

3.2.4.2. Good feeding

The average score of principle “good feeding” in South Korea and the European nations was similar (the differences of the criteria “absence of prolonged hunger” and “absence of prolonged thirst” are 0.61 and 0.05, respectively), but the average score was not very high (Figure 9). It is because the criterion “absence of prolonged hunger” scored very high, while the criterion “absence of thirst” scored lower.

3.2.4.3. Good housing

In the section of principle “good housing,” the score of the criterion “ease of movement” in South Korea was higher than that of the European nations while criteria “thermal comfort” and “comfort around resting” were lower. The score of the criterion “ease of movement” measured by space allowance in South Korea was higher than that of the European nations. The score of the criterion “ease of movement” measured by space allowance in South Korea was higher than that of the European nations (Figure 9). The

space allowance on six farms was above the minimum standards in South Korea, because they are usually raised in the same pen from growing to fattening stage (all-in-all-out). Since this study was conducted during the winter and there were not adequate heating systems in most of the pig houses in this study, the score of “thermal comfort” was lower in South Korea than that of the European nations.

3.2.4.4. Good health

There were 3 criteria in the section on “good health”: “absence of injuries,” “absence of disease,” and “absence of pain induced by management procedures.” The distribution of criteria “absence of injuries” and “absence of disease” is generally similar between South Korea and the European nations (Figure 8). In relation to criterion “absence of pain induced by management procedures,” pigs in eight of the nine farms had tail docking and castration performed without anesthetics in the current study. In addition, it should be mentioned that the farmers in South Korea do not train proper tail docking or castration. The distribution of the European nations in section of “absence of pain induced by management procedures” is 26.86 points higher than those of South Korea (Figure 9), but the European nations also have much lower distributions in this criterion than any other criterion in the principle “absence of health.” Farmers do not use anesthetics for castration surgery because of cost restraints and lack of knowledge. There have been actions to reduce “pain induced by management procedure” in the European nations. In the Declaration of European Commission (154), it is recommended that the surgical castration of piglets be performed with pain

relief from 2012, and surgical castration be phased out completely by 2018. In the European Commission (2016) Council Directive (155), it is recommended that Member States ensure tail docking is not carried out routinely except in case where there is evidence that injuries to sows' teats or to other pigs' ears or tails have occurred. With these recommendations, tail docking and surgical castration that cause unnecessary pain to pigs are banned in the European Community. These moves are believed to have increased the use of anesthetics in European pig farms.

3.2.4.5. Appropriate behaviors

There were 4 criteria in the section on principle “appropriate behaviors”: “expression of social behaviors,” “expression of other behaviors,” “good human relationship,” and “positive emotional state” (QBA). As described above, in the European nations, as in South Korea, the distribution of the criterion “expression of social behaviors” was much higher than that of the criterion “expression of other behaviors.” However, for these two criteria, the average scores of the European nations were 14.67 and 24.07 points higher than those of South Korea, respectively. This seems to have originated from a long-standing study of animal welfare in the European nations. This is because citizens consider behavioral expressions caused by animals' suffering when they form opinions about farm animal welfare (17).

The distribution of the criterion “good human relationship” for growing pig farms evaluated in this study was higher than that of the European nations. In addition, all farms were categorized as “excellent.” According to Hemsworth *et al.* (104), pigs associate a satisfying experience of feeding with

humans and this results in pigs being less fearful of humans. Visual contact with humans may occur when farmers are in the same place as their animals (156). In the section of criterion “positive emotional state,” six of the nine farms (66.7%) in this study were classified as “not classified.” This is more than nine times higher than 7% of the European nations. In addition, the average score of this criterion in the European nations was 42.36 points higher than that of South Korea, which is the biggest difference points between those two regions. We found the reason for this situation because the concern about farm animal welfare by the public in South Korea has just begun.

3.2.4.6. Conclusions

Animal-based parameters have a multifactorial factor and assessment on-farm gives only a snapshot of the status of animals. Moreover, changes in animal status often appear only when the animal is affected by very bad conditions over a long period, and the ability of the animals to compensate is very extensive. The present study revealed clear connections between the results of animal- and environment-based parameters. Since environment-based parameters can be assessed feasibly and precisely, they should be an essential part of the assessment system on farm as the basis for the status of the farm animal welfare quality.

3.3. Summary

This thesis aimed to evaluate the welfare quality of growing pigs in South Korea using animal- and environment-based parameters and reveal the correlation between the two. In addition, the strengths and weaknesses of the welfare status of growing pigs in South Korea were identified by comparing the results of the Welfare Quality® assessment of growing pigs in the European nations and South Korea using animal-based parameters. The results of this study can prove foundational in improving the welfare of growing pigs in the future.

This study assessed nine conventional pig farms for the welfare quality assessment in South Korea using animal-(Welfare Quality® protocol) and environment-based parameters (particularly air quality parameters) during the winter of 2013. The Welfare Quality® protocol, an animal-based parameter, comprise of 12 criteria within four principles, namely, “good feeding,” “good housing,” “good health,” and “appropriate behaviors,” each of which was assessed using one or several measures. Four criteria are combined into an overall assessment to indicate the level of pig farm welfare. Welfare Quality® protocol classifies farms into four categories ranging from “excellent” to “not classified” (below acceptable). The overall assessments found that five out of nine farms to be “acceptable,” four farms to be “enhanced”, and not a single farm to be “not classified.” The principles considering the average score across the nine farms are arranged in a decreasing order as follow: “good feeding” (63.13 points) > “good housing” (59.26 points) > “good health” (33.47points) > “appropriate behaviors” (25.48 points). In terms of principle “good feeding,” eight out of nine farms showed that the criterion “absence of prolonged hunger” scored above 90 points

(farm 5 scored 75 points), and two farms (farm 3 and 5) scored 100 points for the criterion “absence of prolonged thirst.” However, the seven remaining farms scored below 55 points because of poor drinker functionality. In terms of principle “good housing,” among the three criteria within this principle, the criterion “comfort around resting” scored the lowest (53.04 points) because of a high prevalence of bursitis and soiled body. In terms of principle “good health,” low scores were recorded for all farms because of low scores of the criterion “absence of pain induced by management procedures” (mean = 12.33 points). All nine farms performed castration without anesthesia, and eight farms performed tail docking. One farm (farm 6) that did not practice tail docking, scored 46 points, whereas all the other farms scored 8 points. The principle “appropriate behaviors” scored the lowest among the rest. The mean score for the criterion “good human relationship” was 100 points. However, the criteria “expression of other behaviors” (mean = 19 points) and “positive emotional state” (mean = 18.89 points) were the lowest levels within the principle “appropriate behaviors.” A total of 66.7% of the farms reached the acceptable considering the criterion “expression of other behaviors,” but 33.3% of the farms did not reach the minimum score to be classified. Only 33.3% of the farms were ranked at the acceptable level considering the criterion “positive emotional state”; however, 66.7% of the farms did not reach the minimum score for acceptability. Nonetheless, serious animal welfare problems related to the following criteria: 1) “absence of pain induced by management procedures” and 2) “positive emotional state” and “expression of other behaviors.”

Environment-based parameters include the microclimate (temperature, relative humidity, air speed, particulate matter (PM)), airborne bacteria (total airborne bacteria, airborne total coliform, airborne total *e. coli*), concentration of gases (carbon dioxide, ammonia, hydrogen sulfide). Temperature, relative humidity, air speed, and PM concentrate, respectively, ranged from 9.15 to 26.29°C (mean ± SD = 18.62 ± 5.76°C), 39.61 to 100% (mean ± SD = 75.24 ± 21.04%), 0 to 0.04 m/s (mean ± SD = 0.021 ± 0.03 m/s), 192.33 to 1397.25 $\mu g/m^3$ (mean ± SD = 696.34 ± 466.2 $\mu g/m^3$) for PM_{10}, 34.83 to 233.02 $\mu g/m^3$ (mean ± SD = 94.52 ± 77.11 $\mu g/m^3$) for $PM_{2.5}$, 9.2 to 94.22 $\mu g/m^3$ (mean ± SD = 35.45 ± 28.9 $\mu g/m^3$) for PM_1, and 226.75 to 3997.17 $\mu g/m^3$ (mean ± SD = 1385.93 ± 1193.52 $\mu g/m^3$) for total suspended particulate matter (TSP) across the nine pig farms. The concentrations of total airborne bacteria, airborne total coliform, and airborne total *e. coli,* respectively, ranged from 3.33 to 4.36 (mean ± SD = 4.08 ± 0.29 CFU/m^3), 1.87 to 3.82 (mean ± SD = 2.89 ± 0.66 CFU/m^3), and 0 to 3.49 CFU/m^3 (mean ± SD = 2.28 ± 1.05 CFU/m^3) across the nine pig farms. The concentrations of hydrogen sulfide, ammonia, and carbon dioxide, respectively, ranged from 0 to 1.23 ppm (mean ± SD = 0.41 ± 0.42 ppm), 3.69 to 68.17 ppm (mean ± SD = 30.05 ± 26.21 ppm), and 955 to 5583.75 ppm (mean ± SD = 2945.09 ± 1648.04 ppm) across the nine pig farms. The ammonia concentrations and the relative humidity in four out of nine farms were higher than the threshold limit values.

The correlation between animal- and environment-based parameters revealed that temperature and relative humidity had negative correlations

with “abnormal skin” and “coughing,” respectively. Air speed in the pig houses negatively affected “manure score 1,” “lameness score 1,” “hernia score 1,” and the following negative emotional states: “listless,” “indifferent,” and “aimless” (p<0.05). PM did not affect any indicator of this protocol. Total airborne bacteria count had a positive correlation with “coughing” and a negative correlation with the following negative emotional states: “indifferent” and “irritable” (p<0.05). Airborne total coliform had a positive effect on “sneezing,” and airborne total *e. coli* had a positive effect on “manure score 2” and “sneezing” (p<0.05). The analysis also revealed that the concentration of gases in the pig house had a significant influence on the emotional states of pigs. The concentration of ammonia had a negative correlation with positive emotional states, including “content,” “enjoying,” “sociable,” “playful,” “lively,” “happy,” and had a positive correlation with negative emotional states, such as “aimless” and “distressed” (p<0.05). The concentration of carbon dioxide had a negative correlation with positive emotional states, namely, “calm,” “sociable,” “playful,” and “happy” and a positive correlation with negative emotional states, including “aimless”; the concentration of hydrogen sulfide also had a positive correlation with the negative emotional state “fearful” (p<0.05). Overall, animal welfare, particularly the criterion “positive emotional states,” can be improved by controlling air quality for ammonia, hydrogen sulfide, and carbon dioxide, in the correlation between welfare assessment results using animal- and environment-based parameters.

In the the distribution (%) of the overall assessment results for the Welfare Quality® assessment on growing pig farms in South Korea and the European nations, none of the farms assessed in either region were

classified as “not classified.” However, 22% of the farms in the European nations were classified as “excellent,” which is higher than 0% of the farms in South Korea. The European nations and South Korea showed different patterns considering the results of the Welfare Quality® protocol on growing pigs. In principle, the “good feeding” and “good housing” in South Korea were similar to those of the European nations; however, “good health” and “appropriate behaviors” were worse. The low score of the principles in South Korea is mainly attributed to the low scores of the criteria “absence of pain induced by management procedures,” “expression of other behaviors,” and “positive emotional state.” Therefore, expanding related research and establishing legislation is necessary to improve the welfare status in these criteria.

3.4. Limitation

There may be some possible limitations in this study. Firstly, South Korea has a continental, temperate climate with four distinct seasons and is affected by the East Asian monsoon. Winter temperatures are higher along the southern coast and considerably lower in the mountainous interior. Summer is hot and humid, with temperatures exceeding 30°C throughout the country. Because of the climate difference between summer and winter in South Korea, the welfare of pigs should be evaluated in both seasons. However, since farmer did not allow visits during the summer due to the farms’ poor environments and concerns about disease outbreaks, this study was only conducted in the winter. Secondly, at the time of the study, it was

very difficult to acquire permission to assess pig farms because of a foot-and-mouth disease outbreak. Therefore, we were only able to assess nine pig farms. The nine farms involved in this study do not necessarily represent the situation across all regions of South Korea, but this study may still provide useful insight into the welfare on pig farms in South Korea and can serve as a foundation for future welfare studies to improve farm animal welfare; these farms constitute the first pig farms to participate in an independently observed, animal-based welfare assessment study in South Korea. Thirdly, raw data on each of the 207 pig farms calculated in the Welfare Quality® Network were not shown in the report from the Welfare Quality® Network. And all the raw data in the related papers were not assessed under a climate similar to that of South Korea. Therefore, the accurate comparison between two regions was difficult because we had to only use the distributions of the farms and average scores in each stage of the assessment protocol of the European nations on the present study.

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Appendix

Appendix 1. Calculation of scores for growing pigs on farm (Captured from the Welfare Quality® Protocol)

6.2 Calculation of scores for growing pigs on farm

6.2.1 Criterion-scores

6.2.1.1 Absence of prolonged hunger

The % lean animals is turned into a score using an I-spline function as follows (Figure 5):

Let **I** = 100 - % lean animals

When **I** ≤ 80 then Score = (0.010526 x **I**) - (0.00013157 x $\mathbf{I}^2$) + (0.000062487 x $\mathbf{I}^3$)

When **I** ≥ 80 then Score = - 2417.7 + (90.673 x **I**) - (1.1334 x $\mathbf{I}^2$) + (0.0047845 x $\mathbf{I}^3$)

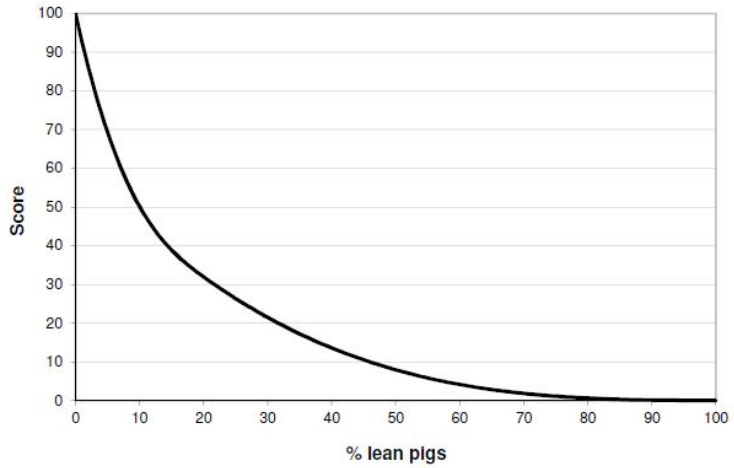


Figure 5 Calculation of scores for absence of hunger according to % lean animals.

6.2.1.2 Absence of prolonged thirst

In each group observed, the number of drinking places, the functioning of drinkers and their cleanliness are taken into account.

The recommended number of pigs per drinking place is set at 10.

When drinkers do not function properly then the number of drinking places is divided by two (= actual number of drinking places).

Then the recommended number of pigs is calculated (= actual number of drinking places x 10) and the number of animals in the pen is compared to that recommendation. If there are more pigs than recommended then the number of drinking places is considered not sufficient.

It is checked whether there are two drinkers available in a pen.

The following decision tree is applied:

Then the score attributed to the whole animal unit is equal to the worst score obtained at group level on the condition that this represents at least 15% of the animals observed from the whole animal unit.

6.2.1.3 Comfort around resting

Two partial scores are calculated, one for bursitis and one for manure on the body, before being combined into a criterion score.

Partial score for bursitis:

The % pigs affected by bursae scored 1 *(%bursae1)* or scored 2 *(%bursae2)* are used to calculate an index:

$$\text{Index } I_b = 100 - \left(\frac{(\%bursae1) + 2(\%bursae2)}{2} \right)$$

This index is computed into a score using I-spline functions as follows (Figure 6):

When $I_b \leq 50$ then $S_b = (1.3213 \times I_b) - (0.026426 \times I_b^2) + (0.00026611 \times I_b^3)$

When $I_b \geq 50$ then $S_b = 33.977 - (0.71734 \times I_b) + (0.014347 \times I_b^2) - (0.0000057116 \times I_b^3)$

<Captured from the Welfare Quality® Protocol>

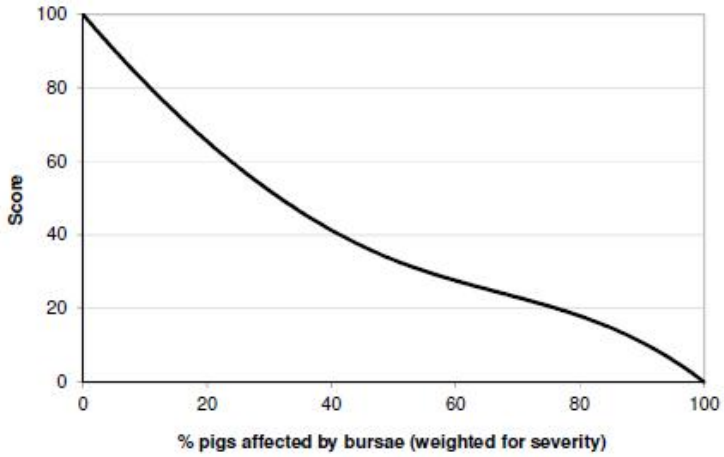


Figure 6 Calculation of partial scores for bursitis according to % pigs affected by bursae (weights 0.5 for pigs affected by mild lesions (bursae score 1) and 1 for pigs affected by severe lesions (bursae score 2)).

Partial score for manure on the body:

The % of dirty (scored 1) and very dirty pigs (scored 2) are used to calculate an index:

$$\text{Index } I_m = \left(100 - \frac{2(\%dirty) + 7(\%verydirty)}{7}\right)$$

<Captured from the Welfare Quality® Protocol>

This index is turned into a score using I-spline functions as follows (Figure 7):

When $I_m \leq 20$ then $S_m = (12.306 \times I_m) - (0.58370 \times I_m^2) + (0.0096231 \times I_m^3)$

When $I_m \geq 20$ then $S_m = 76.823 + (0.78238 \times I_m) - (0.0075336 \times I_m^2) + (0.000020276 \times I_m^3)$

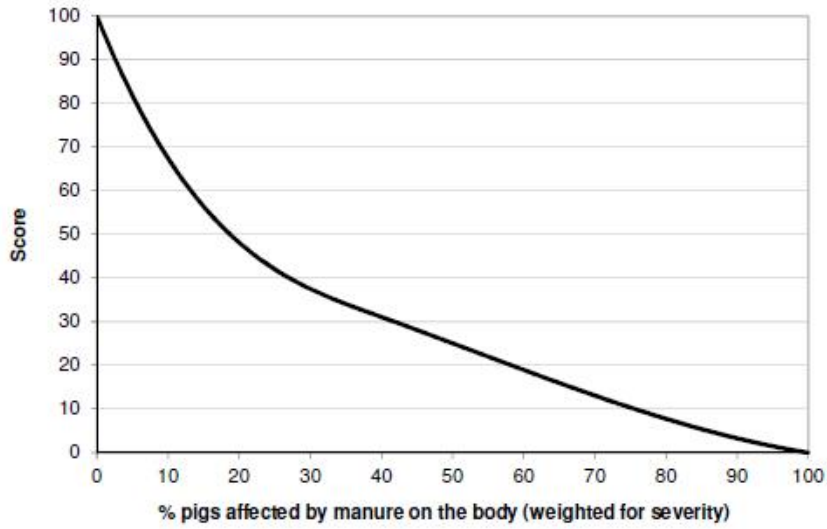


Figure 7 Calculation of partial scores for manure on the body according to % dirty pigs (weights: 0.3 for dirty pigs and 1 for very dirty pigs.

Criterion score

The two partial scores S_b and S_m are combined using a Choquet integral with the following parameters:

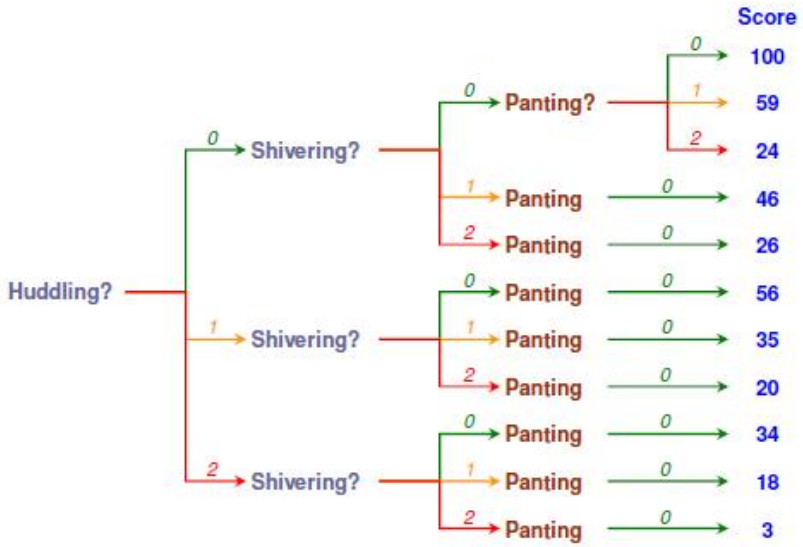
μ_b	μ_m
0.07	0.16

With b, bursitis and m, manure on the body.

<Captured from the Welfare Quality® Protocol>

6.2.1.4 Thermal comfort

The three scores (0, 1, or 2) obtained by a group for huddling, shivering, and panting are merged into one score following a decision tree:



Then the score attributed to the whole animal unit is equal to the worst score obtained at group level on the condition that this represents at least 15% of the animals observed from the whole animal unit.

6.2.1.5 Ease of movement

The following index is calculated from the space allowance:

$I = (100 \times (space\_allowance - 0.3)) / (10 - 0.3)) = (10.3 \times (space\_allowance)) - 3.09$
where space allowance is expressed in m^2/ 100 kg pigs
0.3 m^2/100 kg is considered the very minimal space allowance and 10 m^2/100 kg is considered the maximum.

I is then computed into a score using I-spline functions as follows (Figure 8):

When $I \leq 20$ then Score = $(12.306 \times I) - (0.58370 \times I^2) + (0.0096231 \times I^3)$

When $I \geq 20$ then Score = $76.822 + (0.78238 \times I) - (0.0075336 \times I^2) + (0.000020276 \times I^3)$

<Captured from the Welfare Quality® Protocol>

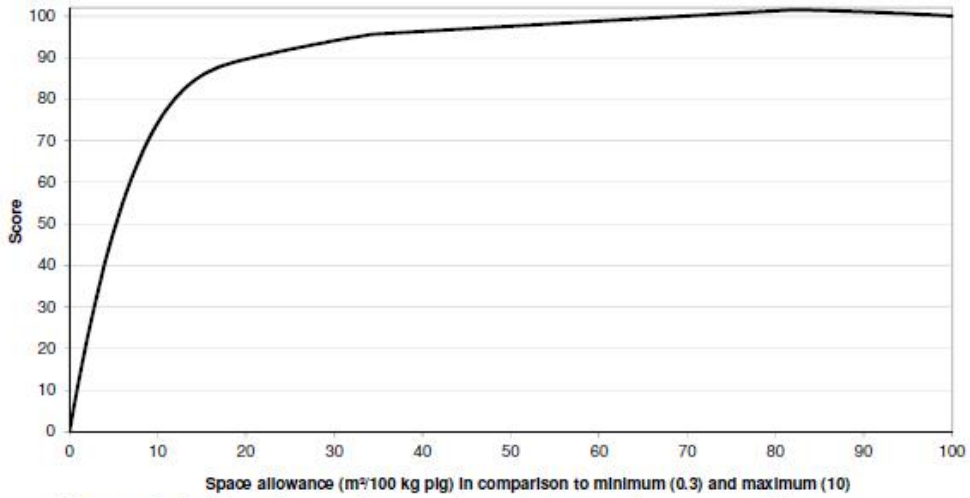


Figure 8 Calculation of scores for ease of movement according to space allowance.

6.2.1.6 Absence of injuries

Three partial scores are calculated:

- One for lameness
- One for wounds on body
- One for bitten tails

These are then combined to form the criterion-score

Partial score for lameness

The % of animals moderately lame (i.e. scored 1 for lameness) and the % of animals severely lame (i.e. scored 2 for lameness) are combined in a weighted sum to form an index I_l:

Index for lameness $$I_l = \left(100 - \frac{4(\%\text{moderate}) + 10(\%\text{severe})}{10}\right)$$

I_l is computed into a score using I-spline functions (Figure 9):

When $I_l \leq 85$ then $S_l = (0.12672 \times I_l) - (0.0014908 \times I_l^2) + (0.000041719 \times I_l^3)$

When $I_l \geq 85$ then $S_l = -11012 + (388.77 \times I_l) - (4.5738 \times I_l^2) + (0.017972 \times I_l^3)$

<Captured from the Welfare Quality® Protocol>

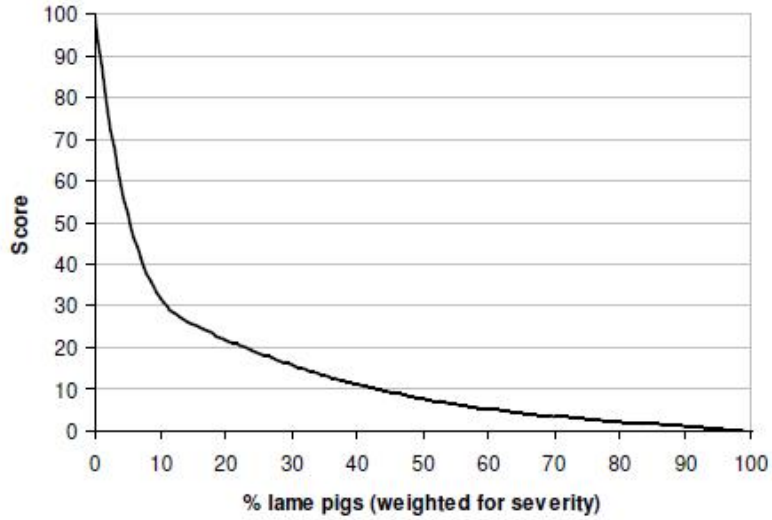


Figure 9 Calculation of partial scores for lameness according to % lame pigs (weights: 0.4 for moderate lameness and 1 for severe lameness).

Partial score for wounds on the body

The % of animals moderately injured (ie scored 1 for wounds on body) and the % of animals severely injured (i.e. scored 2 for wounds on body) are combined in a weighted sum to form an index I_w:

Index for wounds on the body $$I_w = \left(100 - \frac{2(\%\text{moderate}) + 3(\%\text{severe})}{3}\right)$$

I_w is computed into a score using I-spline functions (Figure 10):

When $I_w \leq 40$ then $S_w = (1.1414 \times I_w) - (0.027627 \times I_w^2) + (0.00029385 \times I_w^3)$

When $I_w \geq 40$ then $S_w = 9.3981 + (0.43657 \times I_w) - (0.010006 \times I_w^2) + (0.00014700 \times I_w^3)$

<Captured from the Welfare Quality® Protocol>

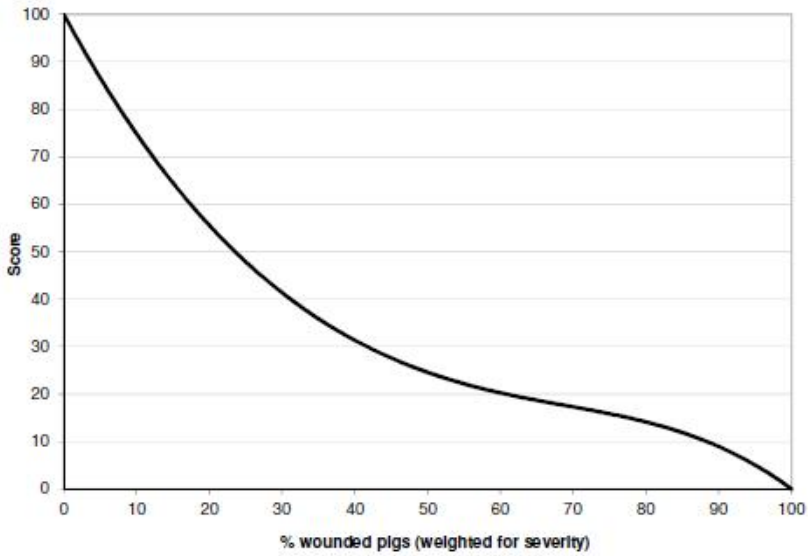


Figure 10 Calculation of partial scores for wounds on body according to % affected pigs (weights: 0.67 for pigs scored 1 and 1 for pigs scored 2).

Partial score for bitten tails:

The % of animals with bitten tail (score 2) is transformed into a score using I-spline functions:

Let I_t = 100 - % of pigs with bitten tail

I_t is computed into a score using I-spline functions (Figure 11):

When $I_t \leq 70$ then $S_t = (0.29648 \times I_t) - (0.0042355 \times I_t^2) + (0.000061694 \times I_t^3)$

When $I_t \geq 70$ then $S_t = -648.04 + (28.070 \times I_t) - (0.40099 \times I_t^2) + (0.0019510 \times I_t^3)$

<Captured from the Welfare Quality® Protocol>

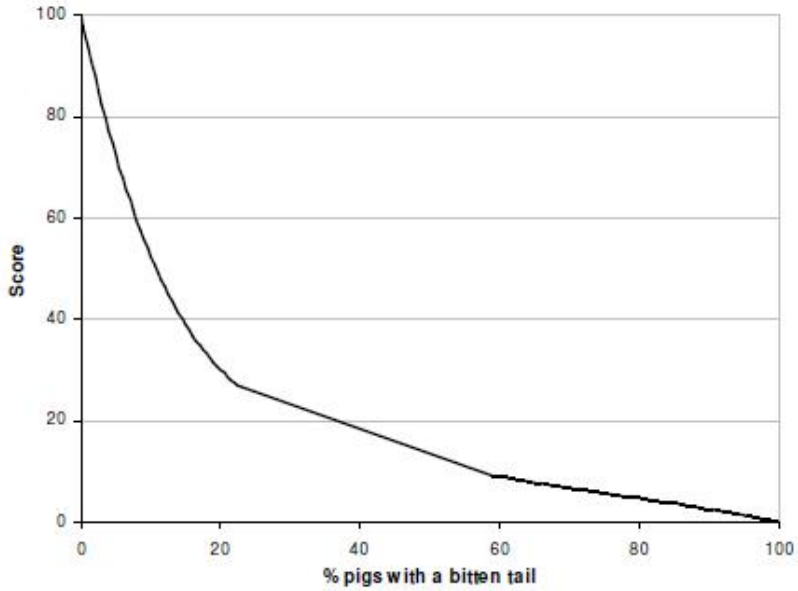


Figure 11 Calculation of partial scores for bitten tails according to % affected pigs.

Score for absence of injuries:
The three partial scores S_l, S_w, S_t are combined into a single criterion score using a Choquet integral. The parameters of the Choquet integral are:

μ_l	μ_w	μ_t
0.29	0.00	0.00

μ_{lw}	μ_{lt}	μ_{wt}
0.37	0.29	0.00

With l, lameness; w, wounds on body and t, bitten tails.

<Captured from the Welfare Quality® Protocol>

6.2.1.7 Absence of disease

The frequency of symptoms is compared to 'warning and alarm' thresholds as follows:

Area	Symptom	Warning threshold	Alarm threshold
Respiratory area	coughing (frequency per pig and 5 min)	15	46
	sneezing (frequency per pig and 5 min)	27	55
	% pigs with twisted snout	1.1	3.5
	% pigs pumping	1.8	5
	% slaughter pigs with pleuritis	28	55
	% slaughter pigs with pericarditis	5	20
	% slaughter pigs with pneumonia	2.7	6
Digestive area	% pigs in herd with rectal prolapse	0.7	2.5
	% pens in herd with liquid faeces	6	15
Liver	% slaughter pigs with white spots on liver (parasites)	10	23
Skin	% pigs with 10% or more skin inflamed	3.1	8
Ruptures and hernias	% pigs with hernias/ ruptures not bleeding, not touching the floor	2.4	5
	% pigs with hernias/ruptures bleeding or touching the floor	0.6	1.5
Mortality	% mortality	2.6	4.5

The symptoms are grouped into 6 areas (see table above).

The severity of problems is estimated per area:

- if in an area, the frequency of one symptom is above the warning threshold and the others are below, then a warning is attributed to the area
- if in an area, the frequency of one symptom is above the alarm threshold, then an alarm is attributed to the area
- if neither, then no problem is recorded

An index is calculated as:

$$I = \left(\frac{100}{6} \times \left(6 - \frac{6(warnings) + 10(alarms)}{10} \right) \right)$$

where *warnings* is the number of areas with a warning
alarms is the number of areas with an alarm

Then the index I is transformed into a score according to I-spline functions as follows (Figure 12):

When $I \leq 10$ then Score = $(0.032168 \times I) + (0.04873 \times I^2) - (0.0014761 \times I^3)$

When $I \geq 10$ then Score = $-1.4891 + (0.47891 \times I) + (0.0040553 \times I^2) + (0.000013045 \times I^3)$

<Captured from the Welfare Quality® Protocol>

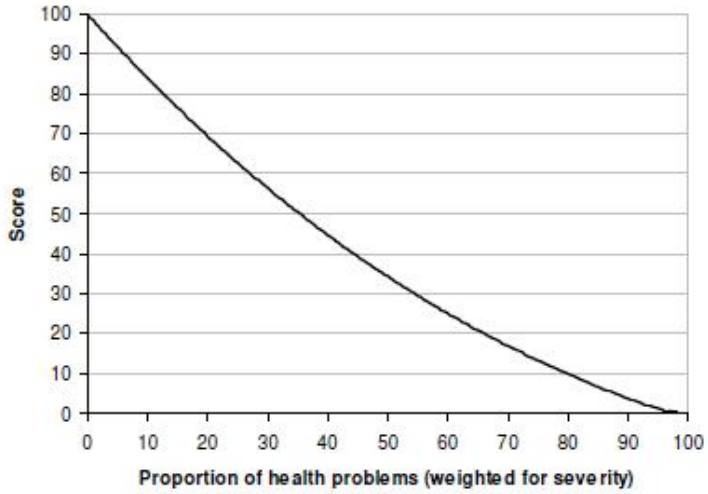
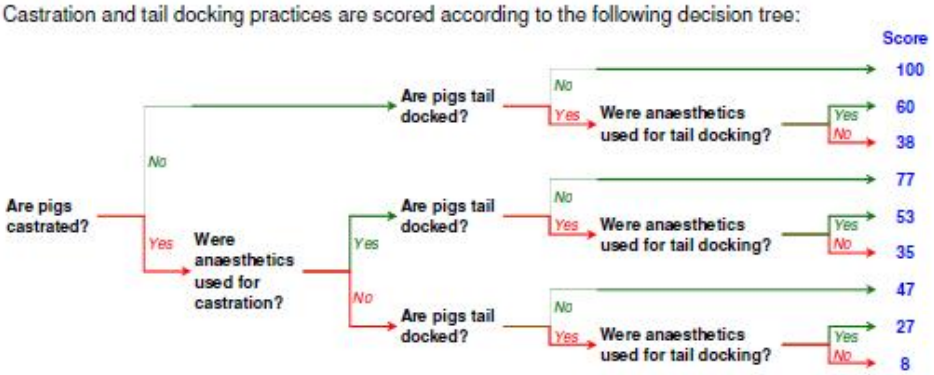


Figure 12 Calculation of scores for absence of disease according to the proportion of warnings and alarms (weights: 0.6 for warnings and 1 for alarms).

6.2.1.8 Absence of pain induced by management procedures

Castration and tail docking practices are scored according to the following decision tree:



6.2.1.9 Expression of social behaviours

An index **I** is calculated from the proportion of negative social behaviour out of all social behaviour:

I = 100 x (1– [proportion of negative social behaviour])

Then **I** is transformed into a score using I-spline functions:

When **I** ≤ 70 then Score = $(1.3426 \times I) - (0.018772 \times I^2) + (0.00015086 \times I^3)$

When **I** ≥ 70 then Score = $-32.920 + (2.7535 \times I) - (0.038927 \times I^2) + (0.00024684 \times I^3)$

<Captured from the Welfare Quality® Protocol>

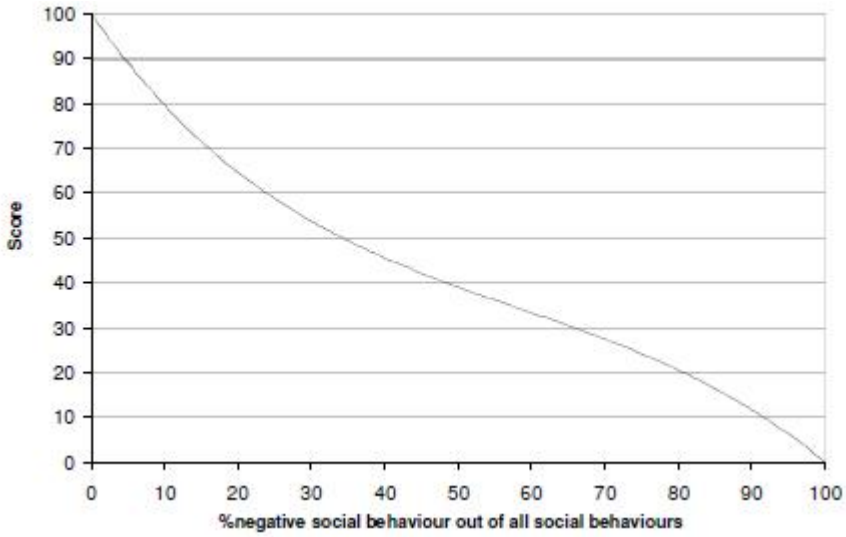


Figure 13 Calculation of scores for expression of social behaviour according to the proportion of social behaviour out of pigs' activities (I_s) and the proportion of negative social behaviour out of all social behaviour.

6.2.1.10 Expression of other behaviours

An index is calculated from the ratio of sample points when exploration of pen features is observed from the total sample points when an active behaviour is observed *(%pen)* and the ratio of sample points when exploration of enrichment material is observed from the total sample points when an active behaviour is observed *(%material)*:

$$\text{Index for exploration } I = \left(\frac{(\%pen) + 2(\%material)}{2} \right)$$

I is transformed into a score using I-spline functions (Figure 14):

When $I \leq 60$ then Score = $(2.2179 \times I) - (0.029761 \times I^2) + (0.00019529 \times I^3)$

When $I \geq 60$ then Score = $65.705 - (1.0674 \times I) + (0.024993 \times I^2) - (0.00010889 \times I^3)$

<Captured from the Welfare Quality® Protocol>

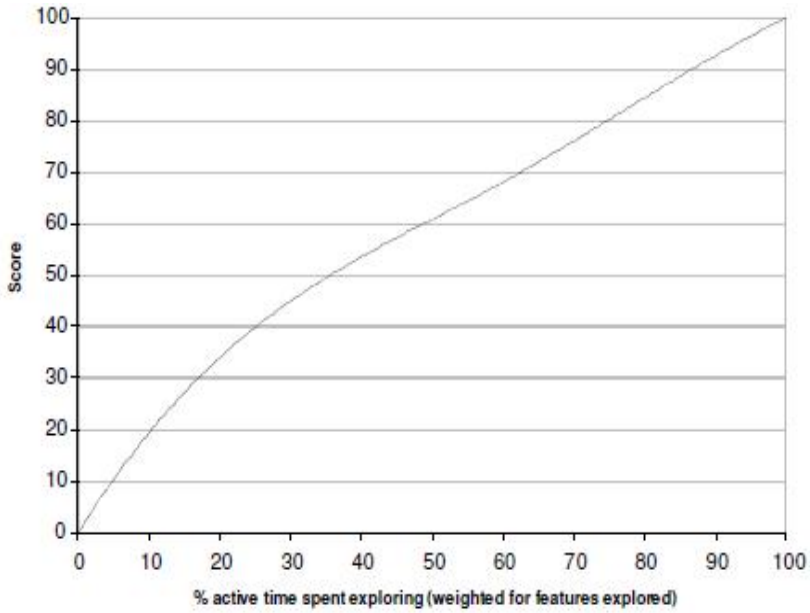


Figure 14 Calculation of scores for the expression of other behaviours according to the % of activity spent in exploration (weights: 0.5 for exploration of pen features and 1 for exploration of enrichment material).

6.2.1.11 Good human-animal relationship

The % pens where a panic reaction (score 2) is observed is transformed into a criterion score using I-spline functions (Figure 15):

Let I = 100 – (% pens scored as 2)

When $I \leq 10$ then Score = $(2.0327 \times I) - (0.15656 \times I^2) + (0.005388 \times I^3)$

When $I \geq 10$ then Score = $5.3849 + (0.41722 \times I) + (0.0049826 \times I^2) + (0.0000030670 \times I^3)$

<Captured from the Welfare Quality® Protocol>

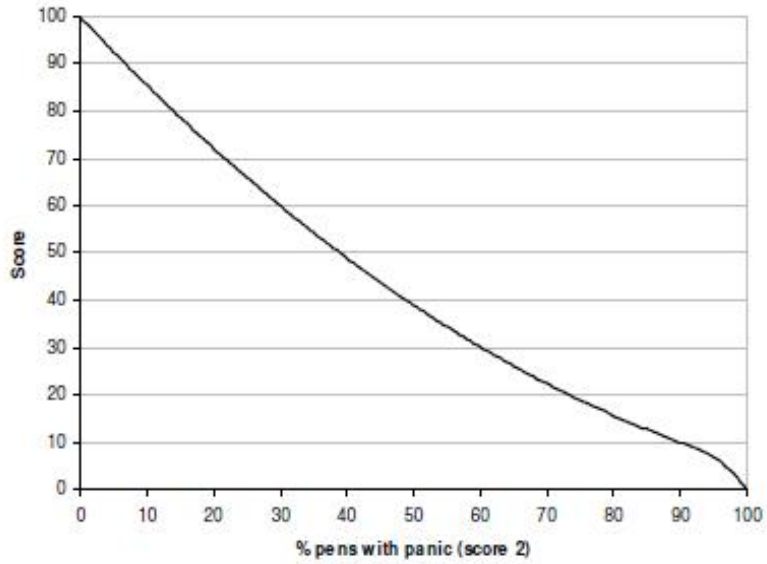


Figure 15 Calculation of scores for good human-animal relationship according to the % of pens where a panic reaction is observed.

6.2.1.12 Positive emotional state

The values (between 0 and 125) obtained by a farm for the 20 terms of the Qualitative Behaviour Assessment are turned into an index thanks to a weighted sum:

$$Index1 = -4.5367 + \sum_{k=1}^{20} w_k N_k$$

with N_k, the value obtained by a farm for a given term k
w_k, the weight attributed to a given term k

<Captured from the Welfare Quality® Protocol>

The weights of the various terms in this sum are:

Terms	Weights
Active	0.01228
Relaxed	0.01087
Fearful	0.00475
Agitated	-0.00711
Calm	0.01122
Content	0.01184
Tense	-0.00971
Enjoying	0.01030
Frustrated	-0.01496
Sociable	0.00544
Bored	-0.01230
Playful	0.00463
Positively occupied	0.01193
Listless	-0.01448
Lively	0.01002
Indifferent	-0.00747
Irritable	-0.00883
Aimless	-0.01193
Happy	0.01193
Distressed	-0.00175

This index is then transformed into a score using I-spline functions (Figure 16) as follows:

When $I \leq 0$ then Score = $-(10 \times I) - (1.25 \times I^2)$

When $I \geq 0$ then Score = $50 + (11.667 \times I) - (0.55556 \times I^2)$

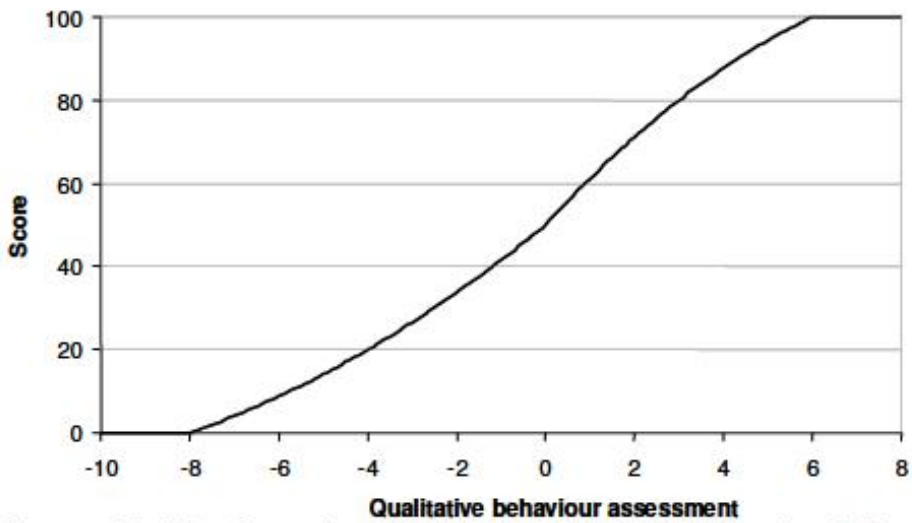


Figure 16 Calculation of scores for positive emotional state according to the values the farm obtained for the various terms used in qualitative Behaviour Assessment (combined in a weighted sum)

<Captured from the Welfare Quality® Protocol>

6.2.2 Principle-scores

Criterion-scores are combined to form principle-scores using Choquet integrals. The parameters of the integrals are given below for each principle.

Principle Good feeding

μ_1	μ_2
0.05	0.28

with 1, Absence of prolonged hunger and 2, Absence of prolonged thirst.

Principle Good housing

μ_3	μ_4	μ_5
0.20	0.11	0.16

μ_{34}	μ_{35}	μ_{45}
0.26	0.33	0.25

with 3, Comfort around resting; 4, Thermal comfort; 5, Ease of movement.

Principle Good health

μ_6	μ_7	μ_8
0.04	0.20	0.09

μ_{67}	μ_{68}	μ_{78}
0.31	0.09	0.20

with 6, Absence of injuries; 7, Absence of disease; 8, Absence of pain induced by management procedures.

Principle Appropriate behaviour

μ_9	μ_{10}	μ_{11}	μ_{12}
0.17	0.01	0.01	0.10

μ_{910}	μ_{911}	μ_{912}
0.22	0.17	0.27

μ_{1011}	μ_{1012}	μ_{1112}
0.13	0.18	0.22

μ_{91011}	μ_{91012}	μ_{91112}	μ_{101112}
0.53	0.63	0.52	0.48

with 9, Expression of social behaviours; 10, Expression of other behaviours; 11, Good human-animal relationship; 12, Positive emotional state.

The principle-scores are always intermediate between the lowest and the highest values obtained at criterion level. Interactions between criteria are substantial within all principles except ' Appropriate behaviour', hence the principle-scores will always be closer to the minimum criterion-scores than to the maximum criterion-scores. Interactions between criteria is limited for Principle 'Appropriate behaviour', leading to compensation between behavioural criteria.

<Captured from the Welfare Quality® Protocol>

Within each principle, some criteria are considered more important than others (and will contribute to a large extent to the principle-score):

- Within principle "Good feeding", Criterion "Absence of prolonged thirst" is considered more important than Criterion "Absence of prolonged hunger".
- Within principle "Good housing", Criterion "Ease of movement" and Criterion "Comfort around resting" are considered more important than Criterion "Thermal comfort".
- Within principle "Good health", Criterion "Absence of disease" is considered more important than Criterion "Absence of injuries" which in turn is considered more important than Criterion "Absence of pain induced by management procedures".
- Within principle "Appropriate behaviour", the order of importance of criteria are: "Positive emotional state" (most important), "Good human-animal relationship", "Expression of social behaviours" and "Expression of other behaviours" (least important).

Examples of principle-scores resulting from criterion-scores are provided in Tables 6 to 9 below.

Table 6 Examples of scores for "Good feeding" according to combinations of Criterion-scores for "Absence of prolonged hunger" and "Absence of prolonged thirst".

Criteria		*Principle*
Absence of hunger	Absence of thirst	*Good Feeding*
40	60	46
50	50	50
60	40	41
75	25	28

Table 7 Examples of scores for "Good housing" according to combinations of Criterion-scores for "Comfort around resting", "Thermal comfort", and "Ease of movement".

Criteria			*Principle*
Comfort around resting	Thermal comfort	Ease of movement	*Good housing*
25	50	75	35
25	75	50	34
50	25	75	37
75	25	50	38
40	50	60	44
40	60	50	44
50	40	60	45
50	50	50	50
50	75	25	34
75	50	25	37
50	60	40	44
60	40	50	45
60	50	40	45

<Captured from the Welfare Quality® Protocol>

Table 8 Examples of scores for "Good health" according to combinations of criterion-scores for "Absence of injuries", "Absence of disease", and "Absence of pain induced by management procedures".

Criteria			*Principle*
Absence of injuries	Absence of disease	Absence of pain induced by management procedures	*Good health*
25	50	75	32
25	75	50	35
50	25	75	30
75	25	50	28
40	50	60	43
40	60	50	44
50	40	60	42
50	50	50	50
50	75	25	38
75	50	25	34
50	60	40	45
60	40	50	41
60	50	40	44

Table 9 Examples of scores for "Appropriate behaviour" according to combinations of Criterion-scores for "Expression of social behaviours", "Expression of other behaviours", "Good human-animal relationship", and "Positive emotional state".

Criteria				*Principle*
Expression of social behaviours	Expression of other behaviours	Good human-animal relationship	Positive emotional state	*Appropriate behaviour*
35	50	50	65	42
35	50	65	50	44
35	65	35	65	42
35	65	50	50	40
35	65	65	35	42
50	35	50	65	39
50	35	65	50	44
50	50	35	65	43
50	50	50	50	46
50	50	65	35	50
50	65	35	50	43
50	65	50	35	45
65	35	35	65	43
65	35	50	50	43
65	35	65	35	45
65	50	35	50	40
65	50	50	35	47
65	65	35	35	46

<Captured from the Welfare Quality® Protocol>

Appendix 2. Correlation between the results of the indicators of the Welfare Quality® protocol and environment-based parameters (full version)

Indicators	TEM[1]	RH[2]	AS[3]	TAB[4]	AC[5]	AE[6]	H_2S	NH_3	CO_2
Bursae score 0	0.433	0.367	0.392	0.458	-0.150	0.000	-0.109	0.233	-0.417
Bursae score1	-0.467	-0.433	-0.511	-0.407	0.133	-0.017	0.234	-0.167	0.383
Bursae score2	-0.151	0.269	0.004	-0.598	-0.176	-0.168	-0.532	-0.235	0.050
Manure score 1	0.267	0.133	-0.681*	-0.441	-0.083	0.033	0.536	0.333	0.367
Manure score 2	0.210	-0.143	-0.25324	-0.145	0.597	.689*	0.662	0.261	0.269
Lameness score1	-0.084	-0.252	-0.781*	-0.316	0.050	0.160	0.789*	0.538	0.151
Lameness score 2	-0.518	0.000	-0.423	-0.632	0.207	0.207	0.520	0.518	.725*
Woundsscored1	0.128	-0.272	-0.635	-0.199	-0.136	-0.017	0.611	0.298	-0.153
Frequency of coughing	-0.127	-0.692*	0.190	0.730*	0.329	0.262	0.318	-0.127	-0.633
Frequency of sneezing	-0.350	-0.417	-0.315	-0.186	.683*	0.700*	.778*	0.617	0.633
Aspect of manure	0.321	0.009	-0.355	0.018	0.125	0.232	.680*	0.410	0.232
Abnormal skin	-0.730*	-0.365	0.082	0.279	0.068	-0.160	0.069	-0.183	-0.068
Hernia score 1	-0.393	-0.117	-0.718*	0.043	0.050	-0.092	0.660	-0.142	-0.092
Positive social Behavior	-0.183	0.417	0.043	-0.322	0.150	0.000	-0.276	-0.717*	0.000
Negative social Behavior	0.128	-0.272	-0.635	-0.199	-0.136	-0.017	0.611	0.298	-0.153
Fearful	-0.479	0.026	-0.371	0.209	0.256	0.180	0.687*	0.410	0.231
Calm	-0.276	-0.527	0.188	0.579	-0.084	-0.201	-0.059	-0.326	-.728*

Content	0.267	-0.083	0.655	0.542	-0.250	-0.350	-0.603	-0.733*	-0.650
Enjoying	0.117	-0.017	0.536	0.322	-0.317	-0.433	-0.628	0-.750*	-0.567
Sociable	0.233	0.017	0.451	0.525	-0.450	-0.550	-0.644	0-.767*	-0.800**
Playful	0.133	0.167	0.332	0.322	-0.283	-0.417	-0.460	-0.867**	-0.667*
Listless	-0.217	-0.250	-0.766*	-0.424	0.117	0.217	0.527	0.617	0.350
Lively	0.167	0.283	0.315	0.288	-0.500	-0.617	-0.561	-0.800**	-0.633
Indifferent	-0.183	0.133	-0.843**	-0.746*	-0.017	0.050	0.301	0.350	0.500
Irritable	-0.075	0.259	-0.795*	-0.698*	0.000	0.075	0.361	0.360	0.552
Aimless	-0.159	-0.151	-0.487	-0.596	0.326	0.418	0.580	0.711*	0.879**
Happy	0.250	-0.167	0.519	0.610	-0.150	-0.267	-0.469	-0.817**	-0.783*
Distressed	-0.126	0.259	-0.551	-0.383	-0.059	0.075	0.517	0.845**	0.577

[1] Temperature (˚C), [2] Relative Humidity (%), [3] Air Speed (m/s), [4] Total Airborne Bacteria Count (CFU/m^3), [5] Airborne Total Coliform (CFU/m^3), [6] Airborne Total *e. coli* (CFU/m^3)

국문요약

본 논문의 목적은 동물 및 환경 기반 변수를 사용하여 한국에서 사육되는 육성돈의 복지 수준을 평가하고, 두 변수 사이의 상관관계를 밝히는 것이었다. 또한 동물 기반 변수를 이용하여 평가한 한국과 유럽 국가의 육성돈 복지 수준을 비교함으로써 국내 육성돈 복지 현황의 장단점을 파악하여, 향후 육성돈의 복지 개선의 근거로 활용하고자 한다.

이를 위해 본 연구는 2013 년 겨울철 동물 기반 변수인 복지 수준® 프로토콜과 환경 기반 변수 (특히, 공기 질 변수)를 이용하여 국내 9 개소 육성돈 농장에 대한 복지 수준을 평가했다. 복지 수준® 프로토콜은 '적합한 먹이', '적절한 사육 환경', '양호한 건강 상태', '정상적인 행동 표현'의 4 가지 원칙 내에서 12 가지 기준으로 구성된다. 각 기준은 하나 또는 여러 지표를 사용하여 평가하였으며, 4 가지 원칙이 하나의 종합평가로 계산되어 양돈농장의 복지 수준을 나타냈다. 복지 수준® 프로토콜은 대상 농장을 '아주 좋음'에서 '기준 미달' (허용 기준 아래)까지 네 가지 범주로 분류하였다.

평가 결과 9 개 농장 중 5 개 농장이 ‘허용’ 범주로 분류되었고, 4 개 농장이 ‘좋음’ 범주로 분류되었으며, '기준 미달' 범주로 분류된 농장은 한 곳도 없었다. 9 개 농장의 평균 점수는 '적합한 먹이' (63.13 점) > '적절한 사육 환경' (59.26 점) > '양호한 건강 상태' (33.47 점) > '정상적인 행동 표현' (25.48 점) 순으로 나타났다. '적합한 먹이' 원칙 중, ‘장기 배고픔 부재’ 기준에서는 9 개 농장 중 8 개 농장이 90 점 이상을 획득했고, ‘장기 갈증 부재’ 기준에서는 2 개 농장 (농장 3 과 5)이 100 점이었지만, 나머지 7 개 농장은 음수대가 제대로 작동하지 않았기 때문에 55 점 이하였다. '적절한 사육 환경' 원칙의 3 가지 기준 중, '편안한 휴식' 기준이 가장 낮은 점수(53.04 점)로 평가되었다. 이는 관절 사이의 윤활낭에 염증이 생기는 질병인 윤활낭염 (bursitis, 潤滑囊炎)과 오염된 신체 (soiled body) 지표의 빈도가 높았기 때문이다. '양호한 건강 상태' 원칙에서는 마취 없이 행해지는 꼬리 자르기나 중성화 등의 ‘관행으로 유발되는 고통의 부재' 기준의 평균 점수가 12.33 점으로 모든 농장에서 낮게 평가되었다. 9 개 농장에서 모두 마취 없이 중성화를 실시했고, 그 중 8 개 농장이 꼬리 자르기를 실시했다. 꼬리 자르기를 실시하지 않은 1 개 농장 (농장 6)은 이 기준에서 46 점을 받았지만, 나머지 8 개 농장은 모두 8 점을 받았다. '정상적인 행동 표현' 원칙은 4 가지 원칙 중 가장 낮은 점수를 받았다. '인간과의 좋은

관계' 기준의 평균 점수는 100 점이었지만, '기타 행동의 표현' (평균 = 19 점)과 '긍정적 감정 상태' (평균 = 18.89 점) 기준은 '정상적인 행동 표현' 원칙 내에서 가장 낮은 수준이었다. '기타 행동의 표현' 기준에서는 농장의 66.7%가 '허용' 범주에 도달했지만, '기준 미달' 범주에 속하는 농장이 33.3%에 달했다. '긍정적 감정 상태' 기준에서는 농장의 33.3%가 '허용'범주로 분류되었으나, 66.7%가 '기준 미달'로 분류되었다. 종합적으로, 한국에서 복지 수준® 프로토콜을 통해 평가된 육성돈 농장 중 '기준 미달'로 평가된 농장은 없었다. 그럼에도 불구하고, 1) '관행으로 유발되는 고통의 부재' 기준과 2) '긍정적 감정 상태'와 '기타 행동의 표현' 기준과 관련된 동물 복지가 제대로 보장되지 않고 있음을 발견했다.

본 연구에서 측정된 환경 기반 변수에는 미세 기후 (온도, 상대 습도, 유속, 미세먼지), 부유세균 (총부유 세균, 총부유 대장균군, 총부유 대장균), 가스 농도 (이산화탄소, 암모니아, 황화수소)가 있다. 온도, 상대 습도, 유속의 결과는 각각 9.15~26.29℃ (18.62±5.76℃), 39.61~100% (75.24±21.04%), 0~0.04 m^2/s (0.021±0.03 m^2/s)였다. 미세먼지 $_{10}$ (PM_{10})은 192.33~1397.25 $\mu g/m^3$ (696.34±466.2 $\mu g/m^3$), 미세먼지 $_{2.5}$ ($PM_{2.5}$)는 34.83~233.02 $\mu g/m^3$ (94.52±77.11 $\mu g/m^3$), 미세먼지 $_{1}$ (PM_{1})은 9.2~94.22 $\mu g/m^3$ (35.45±28.9

μg/m^3), 총부유 미세먼지 (TSP)는 226.75~3997.17 μg/m^3 (1385.93±1193.52 μg/m^3)로 각각 나타났다. 9 개소 농장의 총부유 세균, 총부유 대장균군 및 총부유대장균의 농도는 각각 3.33~4.36 CFU/m^3 (4.08±0.29 CFU/m^3), 1.87~3.82 CFU/m^3 (2.89±0.66 CFU/m^3), 0~3.49 CFU/m^3 (2.28±1.05 CFU/m^3)였다. 또한, 돼지농장 9 개소에서 측정한 황화수소, 암모니아, 이산화탄소의 농도는 각각 0~1.23 ppm (0.41±0.42 ppm), 3.69~68.17 ppm (30.05±26.21 ppm), 955~5583.75 ppm (2945.09±1648.04 ppm)이었다. 환경 기반 변수에서 육성돈의 복지를 저해하는 공기 질 변수는 암모니아 농도와 상대 습도였는데, 농장 9 개소 중 4 개소의 암모니아 농도와 상대 습도가 기준치보다 높게 나타났다.

본 연구에서는 동물 및 환경 기반 변수 사이에 다양한 상관관계가 있음을 밝혀냈다. 돈사 내 온도는 '비정상적인 피부'와 음의 상관관계를, 상대 습도는 '기침'과 음의 상관관계를 가지고 있었다. 돈사 내 유속은 '분변 점수 1', '절름발이 점수 1', '탈장 점수 1', 그리고 부정적인 감정상태인 '무기력', '무관심', '목표 없는' 지표에 부정적인 영향을 미쳤다. 돈사 내 미세먼지는 복지수준® 프로토콜의 어떤 변수에도 영향을 미치지 않았다. 총부유 세균은 '기침'과 양의 상관관계를, 부정적인 감정 상태인 '무관심'과 '초조함'과는 음의

상관관계를 가졌다 (p<0.05). 총부유 대장균군은 '재채기'와, 총부유 대장균은 '분변 점수 2'와 '재채기'와 양의 상관관계가 있었다 (p<0.05). 돈사 내 가스 농도가 돼지의 감정 상태에 큰 영향을 미친 것으로 분석됐다. 암모니아의 농도가 높을수록 긍정적인 감정 상태인 '만족하는', '즐기는', '사교적인', '장난스러운', '활기찬', '행복한' 지표의 점수는 줄어들었으며, 부정적인 감정 상태인 '무의미한'과 '고통스러운'의 점수는 늘어났다 (p<0.05). 이산화탄소의 농도가 높아질수록 긍정적인 감정 상태인 ' 차분함', '사교적인', '장난스러운', '행복한'은 줄어들었고, 부정적인 감정 상태인 '무의미함'은 늘어났으며, 황화수소의 농도가 높을수록 부정적인 감정 상태인 '공포'도 늘어났다 (p<0.05). 결론적으로, 동물 및 환경 기반 변수를 활용한 복지 평가 결과의 상관관계에서 환경 변수 중 특히, 암모니아, 황화수소, 이산화탄소 등 공기 중 가스 농도를 조절함으로써 동물복지, 특히 '긍정적 감정 상태' 기준을 개선할 수 있다는 결론을 내렸다.

동물 기반 변수를 이용해 비교한 한국과 유럽 국가의 양돈 농장 종합평가 분포율을 살펴보면, 두 지역 모두 '기준 미달'로 분류된 곳은 없었지만, 유럽 국가 농장의 22%가 '매우 좋음'으로 분류돼 0%인 한국보다 높았다. 그러나 복지 수준® 프로토콜의 4 가지 원칙의 결과를 비교했을 때, 한국

육성돈의 복지 상태는 유럽 국가와 다른 패턴을 보였다. 한국의 '적합한 먹이'와 '적절한 사육 환경' 원칙은 유럽 국가의 결과와 크게 다르지 않지만, '양호한 건강 상태'와 '정상적인 행동 표현' 원칙은 유럽 국가의 결과보다 나쁜 것으로 나타났다. 특히 국내 돼지 복지 현황 중 문제점으로 지적된 '관행으로 유발되는 고통의 부재'와 '긍정적 감정 상태' 기준을 개선하는 것이 필요하다. 이를 위해 유럽의 동물 복지 관련 제도와 절차를 세밀하게 분석하고, 이를 국내 실정에 맞게 적용할 수 있도록 관련 연구를 확대할 필요가 있다. 또한 동물복지 농장에 대한 인센티브 제공을 확대하는 등 효율적인 제도개선을 추진할 필요가 있다.

주요어: 동물복지, 복지 수준® 프로토콜, 동물 기반 변수, 환경 기반 변수, 공기질 변수, 다기준 평가, 유럽 국가,

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