Ollscoil na hÉireann, Corcaigh

National University of Ireland, Cork

University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Characterization of outdoor pig farms in Ireland using a 'One Welfare' approach

Thesis presented by

Nipuna Sahan Senanayake, Senanayake Mohotti Appuhamilage

for the degree of

Master of Science

University College Cork

School of Biological, Earth and Environmental Sciences

Head of School: Dr Tom Reed

Supervisors: Dr Fidelma Butler, Dr Laura Boyle and Prof Ruth Ramsay

December 2024

Table of contents

Table of contents 2

Declaration 6

Acknowledgements 7

Abstract 8

Introduction 10

1.0 Literature review 14

1.1 Outdoor pig production in the world 14

1.1.1 System description 14

1.1.2 Breed characteristics 15

1.1.3 Challenges 16

1.2 "One Welfare" concept 16

1.3 Pig welfare and outdoor production systems 19

1.3.1 Behaviour of the pigs in outdoor production systems 21

1.3.2 Lesions in outdoor production 22

1.3.3 Lameness in outdoor production 23

1.3.4 Ecto-parasites in outdoor production 24

1.3.5 Gastro – intestinal parasites of pigs 25

1.4 Welfare of the environment in outdoor pig production 29

1.4.1 Soil quality 30

1.4.2 Biodiversity 31

1.5 Outdoor production systems, well-being, and quality of life of the farmer 32

2.0 Effect of the season and age on the welfare of the pigs and the environment of Irish outdoor farms and PCA as a 'One Welfare' approach 36

2.1 Effect of the season and age on animal welfare and environment of Irish outdoor pig farms ... 36
2.1.1 Abstract ... 36
2.1.2 Introduction ... 36
2.1.3 Materials and methods ... 38
2.1.3.1 Farm selection and animals ... 38
2.1.3.2 Animal welfare assessment ... 41
2.1.3.3 Environmental measurements ... 43
2.1.3.4 Statistical analysis ... 45
2.1.3 Results ... 46
2.1.3.1 Body condition score ... 46
2.1.3.2 Lameness ... 47
2.1.3.3 External parasites ... 48
2.1.3.4 Skin lesions ... 48
2.1.3.5 Tail loss and tail lesions ... 51
2.1.3.7 Tear stains ... 52
2.1.3.8 Snout shape and nasal discharge ... 53
2.1.3.9 Soil shear strength ... 53
2.1.3.10 Plant species diversity ... 54
2.1.4 Discussion ... 55
2.1.4.1 Animal measurements ... 55
2.1.4.2 Environmental measurements ... 58
2.1.5 Conclusions ... 59
2.2 A 'One Welfare' analysis of animal, environmental and human welfare of Irish outdoor pig farms ... 61
2.2.1 Abstract ... 61

2.2.2 Introduction......62
2.2.3 Materials and methods......62
2.2.3.1 Animal welfare measurements......63
2.2.3.2 Environmental measurements......63
2.2.3.3 Quality of life of the farmers......63
2.2.3.4 Principal component analysis (PCA)......63
2.2.4 Results......64
2.2.5 Discussion......68
2.2.6 Conclusions......68
3.0 Effects of season, age and parasite management practices on gastro – intestinal parasites of outdoor pig farms in Ireland......71
3.1 Abstract......71
3.2 Introduction......72
3.3 Materials and methods......73
3.3.1 Farms and animals......73
3.3.2 Sample collection......74
3.3.3 Coprological analysis......76
3.3.4 Statistical analysis......76
3.4 Results......77
3.4.1 Parasite taxa......77
***3.4.*2 Prevalence of parasites**......78
3.4.3 Effect of season and age on faecal egg count......79
3.4.4 Effect of using anthelmintics and paddock rotation on faecal egg count......84
3.5 Discussion......87
3.5.1 Prevalence of the parasites......87
3.5.2 Effect of season and age on the faecal egg count......88

3.5.3 Effect of using anthelmintics and paddock rotation on the FEC 89

3.6 Conclusions 90

4.0 Discussion and conclusions 92

4.1 Discussion 92

4.2 Conclusion 95

Bibliography 97

Appendix 115

Declaration

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism.

Nipuna Sahan Senanayake, Senanayake Mohotti Appuhamilage

Acknowledgements

There are many people to whom I am deeply grateful for their support and guidance during the course of my master’s program.

Firstly, I would like to express my heartfelt thanks to Dr Laura Boyle, Dr Fidelma Butler, and Prof Ruth Ramsay for their immense support and mentorship throughout my time in Ireland. Their calm demeanour, accommodating nature, and reassuring presence were invaluable, especially during moments of stress.

I am also deeply thankful to Dr Ophelie Menant for her tremendous support during our data collection visits to outdoor pig farms across Ireland. Her partnership and camaraderie made what could have been a challenging process both enjoyable and stress-free. My sincere thanks also go to Dr Keelin O’Driscoll for her valuable advice and support during my time at Teagasc Moorepark.

I am incredibly grateful to the Pig and Poultry Development Department at Teagasc Moorepark and the broader Teagasc community for hosting me during my Walsh Scholarship program. Under the leadership of Dr Edgar Manzanilla, the department members warmly welcomed me, helping me settle in and ensuring my work proceeded smoothly.

A special note of thanks goes to my family—my wife, Thulani, my father, and my late mother—for their unwavering faith in me and their encouragement to pursue research in a distant country. Their support has been a cornerstone of this journey.

Lastly, I am profoundly grateful to the outdoor pig farmers who generously accommodated us during our visits and to the pigs themselves, who tolerated our constant observations and interventions. I would also like to thank the Department of Agriculture, Food and the Marine of Ireland, as well as the people of Ireland, for funding my scholarship and providing me with a welcoming home away from home.

To everyone who contributed to this journey, I extend my deepest gratitude.

Abstract

Outdoor pig farming is gaining attention for its alignment with growing consumer interest in animal welfare and environmental sustainability. Unlike intensive systems, outdoor farms offer pigs access to soil and vegetation, encouraging natural behaviours such as rooting and foraging and minimising damaging behaviours and the associated body lesions. However, challenges such as seasonal weather effects, degradation of the soil, and greater exposure to gastrointestinal parasites pose risks to animal welfare and environmental health. This thesis explores the interconnections between animal welfare, environmental parameters, and farmer well-being in outdoor pig farming systems in Ireland using a 'One Welfare' approach. Welfare and environmental measures were assessed in 446 pigs across 20 outdoor pig farms in Ireland during two seasonal visits (1st visit - February–May 2nd visit - July–October 2023). Welfare indicators included body condition score (BCS), lameness, skin lesions, and prevalence of ecto-parasites, while environmental parameters focused on soil shear strength and plant diversity across distinct paddock areas (foraging, defecation, and low-impact areas). Majority of the pigs were in good welfare and there were only minor seasonal effects ($P < 0.05$): higher lameness and ecto-parasite prevalence in the 1st visit, and higher lesion counts at the 2nd visit. Older animals (i.e. sows and boars) exhibited poorer welfare outcomes than fattener pigs, including higher lameness scores, lesion counts, and ecto-parasite prevalence ($P < 0.05$). Soil structure was significantly weakened in foraging areas during the 2nd visit, while the diversity of plants declined from the 1st to the 2nd visit in the foraging area. The relationships between animal welfare, environmental parameters, and farmer well-being was explored using a holistic approach. Data from 223 pigs across 17 farms during the second seasonal visit (July–October 2023) were analysed using principal component analysis (PCA), revealing three distinct clusters. Cluster 1 was characterized by poor animal welfare (high lameness, skin lesions, and ecto-parasite prevalence), primarily relating to sows and boars. Cluster 2 was associated with organic or GMO-free farms, with higher animal welfare but with the lowest scores for farmer well-being. Cluster 3 achieved a balance of high animal welfare and farmer well-being, typically involving fattener or grower pigs. Significant differences ($P < 0.05$) between clusters were observed for soil shear strength and plant diversity in specific paddock zones, highlighting trade-offs between welfare dimensions.

The second study focused on gastrointestinal parasite prevalence and its associations with management practices. A total of 65 paddock-level faecal samples, collected over two visits for the same farms mentioned above, were analyzed using the McMaster flotation method. Four parasite taxa were identified: *Eimeria* spp., strongyles, *Ascaris suum*, and *Trichuris suis*. Infection rates exceeded 80% for *Eimeria* spp. and strongyles, 31% for *A. suum*, and 9% for *T. suis*. Seasonal differences were evident, with *Eimeria* spp. counts significantly higher in the second visit ($P < 0.001$) and strongyles higher in the first ($P < 0.05$). Fattener pigs had higher *Eimeria* spp. counts ($P < 0.01$), while sows/boars had higher strongyle counts ($P < 0.05$). Strongyle FEC was reduced with anthelmintic usage ($P < 0.05$), while paddock rotation mitigated *Eimeria* spp. counts when anthelmintics were administered. This thesis provides the first comprehensive evaluation of animal welfare, environmental quality, and farmer well-being in outdoor pig farming systems in Ireland. The findings highlight the importance of season-specific management strategies and the importance of the interplay between animal, environment and the human, providing a holistic understanding of 'One Welfare' in Irish outdoor pig farms.

Keywords – Outdoor, pig, Ireland, One Welfare, parasites

Introduction

Pork is one of the most consumed meats in the world (Kim et al., 2024). Global pork consumption was at 34% in 2022, compared to 40% of beef and 22% of poultry (OECD, 2023). The pig (*Sus scrofa domesticus*) population in the world is estimated at 978 million in 2022 (FAO, 2022). The majority of the pigs are raised in intensive farming systems. The features of this production system include improved animal nutrition, good feed efficiency, health management, genetic selection for better performance, and consistency of product quality and delivery to the marketplace. However, pigs are reared in these systems under limited space in barren environments and on concrete floors which is different from the environment in which the pig evolved (Van De Weerd & Day, 2009). World population is increasing and pork meat consumption is expected to double within the next 30 – 50 years (McGlone, 2013). Increasing demand in a highly cost: price driven industry forced producers to find ways to increase production while minimising the associated costs such that animal welfare is impaired (Whittemore, 2018). Pigs have evolved to root and perform exploratory behaviours and in barren environments with limited space allocation, and there's an increase in abnormal and stereotypic behaviours and associated physiological distress (Stolba and Wood – Gush, 1983; Van De Weerd and Day, 2009). Abnormal behaviours such as tail biting are particularly injurious and necessitated docking pigs tails soon after birth which is unacceptable societally (Martelli, 2009) and subject to control under EU legislation (EU Directive 2008/120/EC). Furthermore, consumer attitudes towards the environment and nature, as well as animal welfare, points to a need for higher standards in food production (Krystallis et al., 2009) . US consumers also increasingly iterate the importance of naturalness (natural feeding, behaviours and life) in pig production (Sato et al., 2017). These concerns are paving the way for alternative systems of pig production to improve animal welfare.

Outdoor pig production is defined as a system that allows pigs outside access including contact with soil and growing plants (Honeyman et al., 2001). Rearing pigs outdoors is an ancient farming tradition but recent advances in housing and fencing means that it is seeing a resurgence around the world (Honeyman et al., 2001). The main feature of this system to have an outdoor run where pigs have access to soil. This system also allows the pigs to perform their natural behaviours such as rooting and exploring, which comprises 75% of the pigs waking hours in a natural environment (Stolba and Wood – Gush, 1983).

Season and the climatic environment affects many aspects of outdoor pig farming, including animal welfare and growth performance (Park et al., 2017; Pietrosemoli & Tang, 2020). Piglet mortality in outdoor systems can be higher in comparison to conventional systems (Park et al., 2017). The other challenges includes incidence of parasites, especially the prevalence of gastro – intestinal parasites.

Parasites are common in outdoor pig production as soil provides an excellent medium especially for gastro – intestinal parasites, and their effect depends on the parasite burden and host response (Kipper et al., 2011). Most common gastro – intestinal parasites in pigs according to previous studies are the intestinal nematodes *Ascaris suum*, *Oesophagostomum spp.* and *Trichuris suis* as well as coccidia species such as *Isospora suis* in piglets and *Eimeria spp.* in adults (Roepstorff et al., 1998). Gastro – intestinal parasites cause clinical diseases or it could lead to a subclinical infection that might lead to reduced weight gain, feed conversion and welfare (Pettersson et al., 2021).

The environment where the pigs are reared can lead to the loss of soil structure and a higher potential for bio – diversity degradation (Halberg et al., 2010; Horta et al., 2022) . Pigs which are kept in a high density outdoor environment could expose the soil through behaviours such as rooting, and that could lead to runoff and erosion (Pietrosemoli & Tang, 2020). Furthermore, high stocking density results in large net input of nutrients and increased risk of nitrogen leaching (Eriksen & Kristensen, 2001). Farming has been considered a stressful occupation and farming can be difficult especially for the outdoor pig farmers with lack of support from the government, high feed price and the competition from conventional systems could effects the well – being of the farmer (Brajon et al., 2024). At the same time, farmer could be motivated by the potential 'positive' animal welfare provided by the outdoor system (Kling-Eveillard et al., 2007).

Assessing animal welfare is complex, as multiple factors must be taken into account. The five freedoms concept is the most widely accepted concept of defining animal welfare, however this evolved into the five domains of animal welfare to include the positive emotions of the animal as well as the negative emotions (Webster, 1994; Mellor, 2017). Animal welfare could be connected to the well – being of the farmer, and the well – being of the environment. 'One Welfare' is a concept emphasizing the interconnectedness between the animal, the environment and the human welfare and argues that improvements or impairments in each areas can influence each other (Pinillos et al., 2016). Furthermore, this concept encourages a holistic look at the welfare of the system. This approach was employed to look at the interconnections between the animal, the environment and the farmer in outdoor pig production systems in Ireland.

The pig industry in Ireland is highly intensive. In the Republic of Ireland, there were 91 pig herds with an average size of 864 animals in 2023 (Teagasc, 2023). With highly prolific sows (27.9 piglets per sow per year), the industry is expanding. Pig welfare standards in Ireland are derived from the European Union pig welfare directive (Directive 2008/120/EC) and by the national legislation of Animal Health and Welfare Act 2013 (Department of Agriculture, Food and the Marine, 2020). However, almost all welfare guidelines are directed towards conventional indoor production systems. Data on outdoor pig systems are limited. Menant et al. (2023) conducted a survey on Irish outdoor pig farmers on the Island of Ireland, and found the outdoor pig production to be small-scale, mostly 'back-yard' industry. The majority of outdoor farmers were raising pigs as a secondary option.

This thesis has three chapters and the first chapter provides background information on the 'One Welfare' framework and the welfare and the environmental indicators. The second chapter is in two parts and the part one is about the seasonal variations of animal and selected environmental indicators in Irish outdoor pig farms. The second part is about the preliminary principal component analysis to reflect 'One Welfare' type analysis. The third chapter focuses on the gastro – intestinal parasites of the outdoor pig farms and provides the situation on the gastro – intestinal parasites. The fourth chapter provides an overall discussion and provides conclusions from the overall study.

Chapter 01

Literature review

1.0 Literature review

1.1 Outdoor pig production in the world

Pork is the second highest consumed meat in the world at 125 million metric tons in 2021, and this is likely to increase (FAO, 2021). Pig production is mainly intensive, where the farming is sophisticated and on an industrial scale with efficient use of land with high capital investments (Whittemore and Kyriazakis, 2008). Extensification of pig farming offers the potential for extra compensation for organically or outdoor produced meat or for compliance with additional animal welfare requirements (Köppel et al., 2007). Additionally there is growing societal pressure to improve welfare, which is encouraging production of pigs outdoors (Pugliese et al., 2004). Outdoor pig production has rapidly expanded in parts of Europe, South Africa, and the United States with wide ranging farm sizes, from small (<10 sows) to very large (10,000 sows) (Honeyman, 2005) . Recent data shows over 9 million organic pigs produced in Europe, indicating a growth of 46% from 2007 to 2015 (Delsart et al., 2020). However, as a proportion of total pig production, outdoor pig production remains small (Delsart et al., 2020).

1.1.1 System description

Outdoor pig production is defined as a system where the pigs are allowed outside access, including contact with the soil and growing plants (Honeyman et al., 2001). Typical characteristics of an outdoor pig production system include simple portable housing, water systems and feeding, extensive fencing, seasonal production and minimal energy requirements (Honeyman et al., 2001). Besides welfare considerations, outdoor systems offer potential environmental and social benefits and require lower capital investment than commercial indoor systems (Hötzel et al., 2004; McGlone, 2001). Advances in electric fencing, all-terrain vehicles, plastic ear tags, low-cost plastic water pipes and improved farrowing huts made modern outdoor pig production competitive and easier to manage (Honeyman et al., 2001).

Outdoor production systems come in many forms (Edwards, 2005) . Outdoor systems in the US are primarily used for gestation sows, where 5% of sows are kept outdoors and 15% of the sows are kept in buildings with outdoor access (Honeyman, 2005). Over 20 years ago, in some European countries, as in the UK and France, a significant number of outside herds were contributing to conventional pig meat supplies (Edwards, 2005). In the UK, there are around 875,000 productive sows reared in outdoor environments in 2023 (AHDB, 2023). Compared to other countries in Europe, up to 40% of sows in the UK are bred outdoors (Ottosen et al., 2021).

Two common types of outdoor system are described in Sweden. The mobile system, where the feed and shelter are moved with the pigs to new areas and the stationary system, where stationary barns are connected to an outdoor area (Salomon et al., 2007). European outdoor production systems are separated into different production phases. The grower herd is kept in semi intensive conditions where they have access to a pen with straw bedding (Miao et al., 2004). In general, approximately, 50% of outdoor bred piglets are transferred to intensive indoor units in the finishing phase. As a general practice in the outdoor pig production, gilts are kept in an area in small groups where they have access to mud wallows. A week before farrowing, they are transferred to individual grassy paddocks with insulated arcs and abundant straw bedding. Piglets are weaned at 24 days and the sows go back into the group until the next farrowing (Miao et al., 2004). Another major European outdoor system is the traditional Mediterranean silvo-pastoral system (Edwards, 2005). In this system, indigenous breeds are reared in natural forests, sometimes in extreme conditions in the mountain zone (Edwards, 2005). The animals are completely reared outdoors and eat acorns and chestnuts from the forest, where they live, thus converting them to body fat deposits (Edwards, 2005). These systems are in parts of southern and central Spain, Portugal and Italy (Edwards, 2005)
.

1.1.2 Breed characteristics

In general, the physical condition of the pigs in outdoor systems needs to be more robust to withstand the rigors of the climate (Edwards, 2005) . Many outdoor systems use traditional breeds as their sturdiness and resilience is advantageous. In the US, outdoor pig producers prefer crossbred sows, using a primarily white breed or lines (Yorkshire and Landrace) with a smaller percentage of dark breeds or lines (Duroc or Hampshire) (Honeyman et al., 2001). In organic systems, emphasis is placed on using traditional breeds adapted to the local conditions and extensive production systems (Edwards, 2005).

1.1.3 Challenges

Piglet mortality following birth is a concern for many outdoor pig farms and many studies observed high mortality in outdoor farms compared to intensive farms, with most deaths occurring during the first four days of a piglet's life (Mortenson et al., 1994; Rangstrup-Christensen et al., 2018; Delsart et al., 2020) . Biosecurity is also a concern for the outdoor farms, as implementing biosecurity measures can prove to be difficult in an outdoor setting and can be expensive (Edwards et al., 1994). Good management can raise productivity close to that seen in indoor pig farms, however the weather can have dramatic effects on growth rate which is difficult to control (Miao et al., 2004).

Menant et al. (2023) conducted the first survey of outdoor pig farmers in Ireland. The farms were operated at a small scale with an average of 7 sows/gilt, 1 boar, 18 grower pigs and 17 piglets at any one time during the year and managed by, on average, two people. Pastures were common (74.5%) and pigs were also kept in woodlands (37.3%) and scrublands (37.3%) with average 18.5 animals per hectare. Main breeds reared were Duroc (35.8%), followed by Oxford sandy and black (32.1%), Tamworth (22.6%) and Gloucester old spot (20.8%).

1.2 "One Welfare" concept

The concept of welfare is defined by (Broom, 1986) as "The welfare of an individual is its state as regards its attempts to cope with its environment". Animal welfare as a science began over the last 30 years and developed as a measurable quality of life of a living animal at a particular time (Broom, 2014). Traditionally, welfare of humans and non-human animals were seen as distinct disciplines, however, although separated and compartmentalized, these disciplines rely on the same set of principles and are heavily dependent on each other in an ecological context (Colonius & Earley, 2013).

There are a number of concepts that portrays animal welfare; the most used one being the concept of five freedoms. Developed by Webster (1994), this concept details the broader dimensions of animal welfare by incorporation of subjective experiences, health status and behaviour (Webster, 1994; Mellor, 2017). The five freedoms are listed as below;

1. Freedom from thirst, hunger and malnutrition
2. Freedom from pain, injury and disease

3. Freedom from discomfort and exposure
4. Freedom from fear and distress
5. Freedom to express normal behaviour

Another model, the five domains of welfare was developed from the five freedoms concept and there is a growing interest in this concept from various animal use sectors (Mellor, 2017). This model facilitates assessment of animal welfare in a systematic, structured, comprehensive and coherent manner (Mellor, 2017). The features of the model are seen infigure 1.1.

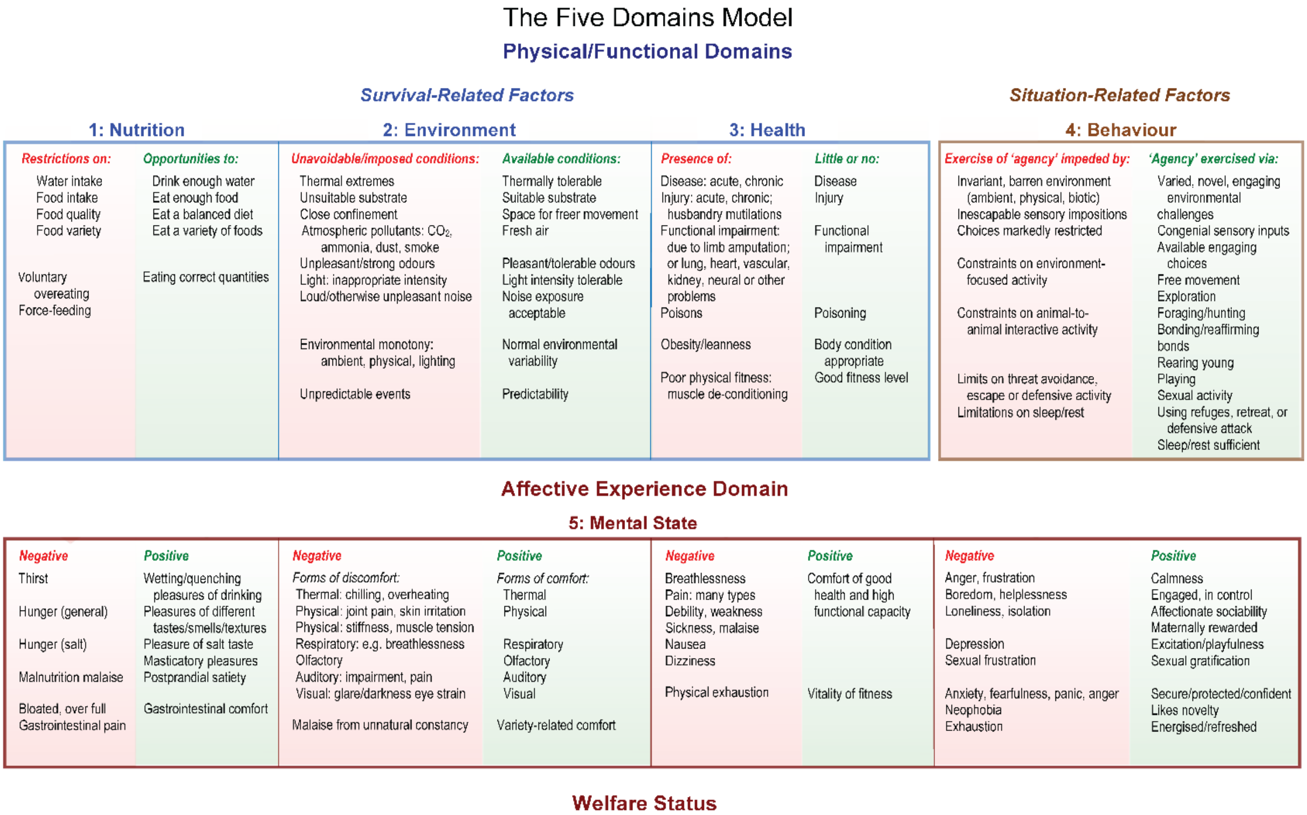

Figure 1.1 – The five domains model (Mellor, 2017)

The concept of “One Health” promotes the integration of human, animal and environmental health through communication and collaboration among physicians, osteopaths, veterinarians, wildlife professionals, environmental and public health experts, dentists, nurses, biomedical engineers, physicists, bio-chemists, plant pathologists, and others (Monath et al., 2010). One Health philosophy resulted in beneficial synergies, such as better understanding of disease processes, through a comparative medicine approach involving public health, environmental health, biomedical health and clinical medicine and surgery (Monath et al., 2010).

World bank defines One Health as “A collaborative approach for strengthening systems to prevent, prepare, detect, respond to and recover from primarily infectious diseases and related issues such as antimicrobial resistance that threaten human health, animal health, and environment health, collectively, using tools such as surveillance and reporting with endpoint of improving global health security and achieving gains in development” (World bank, 2018).

A One Welfare approach complements the “One Health” approach and helps to empower animal welfare and human wellbeing fields to address the connections between science and policy more effectively in various areas of human society, including environmental science and sustainability (Pinillos et al., 2016). One Welfare is a term, which describes the interrelationships between animal welfare, human wellbeing and the physical and social environment (Pinillos, 2018). According to the One Welfare concept, human welfare and non-human animal welfare are interconnected, such that poor animal welfare in production systems means animals are more inefficient meaning negative effects on human welfare (e.g. reduction of profitability) (Tarazona et al., 2019). Another component in this, which is the environment, is also affected by the actions from the human - animal relationship, most notably in livestock production where there are environmental concerns arising from greenhouse gas emissions from animal husbandry (Tarazona et al., 2019). The One Welfare concept looks at all three components and provides a holistic understandings into the welfare issues effectively extending as well as complementing the concept of One Health.

Since One Welfare is a multifaceted concept that covers a broad range of fields, a conceptual framework that arranges different areas helps us to better understand the concept (Pinillos, 2018).

According to Pinillos (2018), the One Welfare framework is made up of five sections, numbered in no particular order;

1. Section 1: The connections between animal and human abuse and neglect.
2. Section 2: The social implications of improved animal welfare.

3. Section 3: Animal health and welfare, human wellbeing, food security.
4. Section 4: Assisted interventions involving animals, humans and the environment.
5. Section 5: Sustainability: Connections between biodiversity, the environment, animal welfare and human wellbeing.

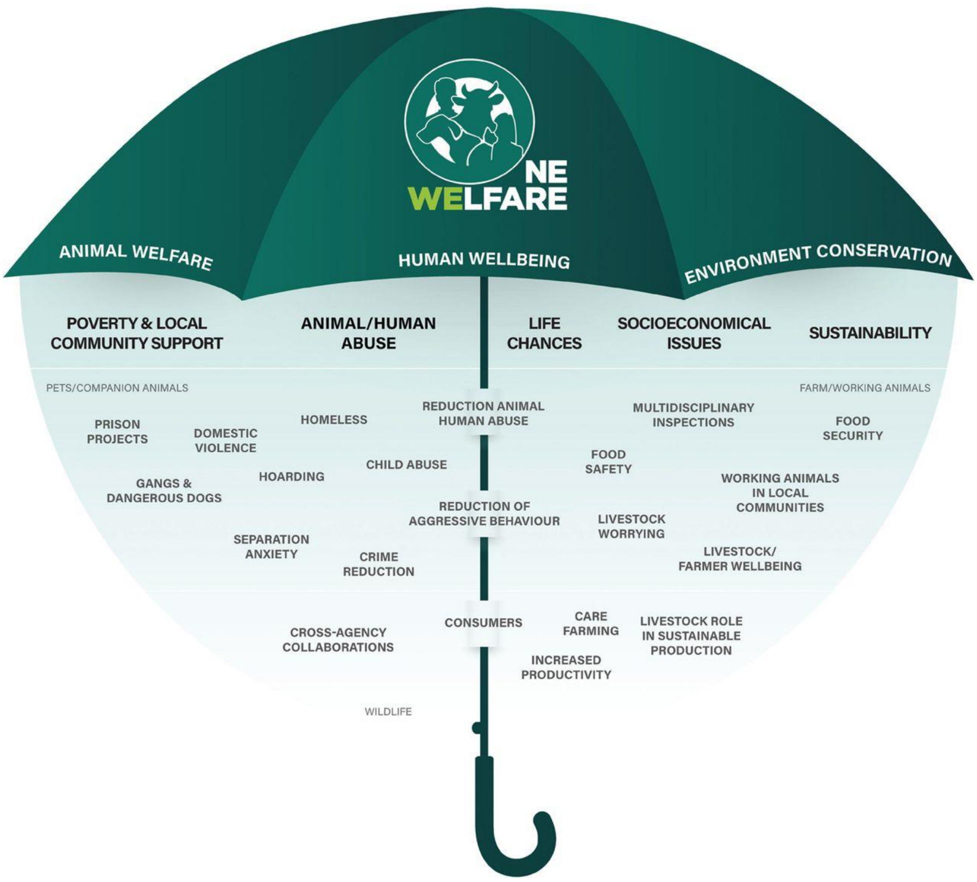

Figure 1.2 – One Welfare and the subjects that falls under the One Welfare umbrella

Source – onewelfareworld.org, (accessed on 21st November 2023)

1.3 Pig welfare and outdoor production systems

Rearing pigs under free-range outdoor conditions is expensive. A study by Bornett et al. (2003) in the UK found that it costs 4 – 8% more to implement higher welfare in "freedom food" and free-range systems. Pigs reared under organic standards cost 31% more than that of conventional systems. A study undertaken by Spooner et al. (2014), in Canada, revealed that citizens have a positive interest and support that pigs should have access to natural living conditions and an ability to express their natural behaviours. Carlsson et al. (2005) found that Swedish consumers were willing to pay surprisingly high premiums for some animal welfare improved quality attributes, including outdoor pig production. (Boogaard et al., 2011) interviewed citizens from the Netherlands and Denmark, and they noted that the citizens were strongly concerned about overexploitation of pigs in contemporary production systems. According to Honeyman (2005), natural outdoor reared pork meat caters for niche markets, where consumers are interested in food safety and food origins.

Although perceived as providing higher welfare, there can be instances where welfare is compromised in outdoor systems, especially in case of parasitic infections, which can be more severe than in conventional systems, in addition to the adverse effects of poor climate (Edwards, 1999). This will be discussed further in another chapter of this thesis (see Chapter 2). There are studies that contradict the general beliefs of better welfare in outdoor systems. Kongsted & Sørensen (2017) assessed the lesions found in pigs upon slaughter in three different rearing systems (conventional indoor, conventional free – range and organic free – range) in Denmark and found higher scores of tail lesions, skin lesions and arthritis for the latter two systems compared with conventional indoor pigs.

McGlone (2013) compared outdoor production systems with indoor production systems in a sustainability matrix. The perception of the public towards welfare and the meat quality (real and perceived) was higher in the outdoor system. However, outdoor systems scored poorly in terms of climate variability, worker health and safety, food safety (*Salmonella*), and zoonotic diseases.

Guy et al. (2002) conducted a study in the UK, to compare the welfare in three different pig-rearing systems. They found that the pigs reared in outdoor paddocks had significantly lower lung damage, arising from enzoonotic pneumonia, compared to the indoor breeds. Temple et al. (2012) reported that Mallorcan black pigs reared in extensive systems presented a higher risk of poor body condition compared to the pigs in conventionally reared pigs. Five percent of the pigs in the extensive systems were entirely dependent on pasture and the authors believe that this might have led to the increased risk of poor body condition. Other pigs were reared in a mixed system.

1.3.1 Behaviour of the pigs in outdoor production systems

As pigs are omnivorous animals, they spend a large part of their active time in searching for food and exploring the area under natural conditions (Studnitz et al., 2007). This behaviour keeps the pigs from lacking resources for their survival, thus rooting is considered as a high priority behaviour in pigs (Studnitz et al., 2007) . Domestic pigs allowed to live freely in an outdoor woodland setting spend 75% of their time foraging and feeding, even when they are fed *ad libitum* (Stolba and Wood-Gush, 1989). Indeed, they show similar behaviours to wild boar, who spend 85% of their active day dedicated to this behaviour (Stolba and Wood-Gush, 1989; Olczack et al., 2015). Pigs engage in a great amount of rooting behaviour, when the opportunity is given, as it's considered as a part of their normal ethogram (Millet et al., 2005).

As one of the main goals of outdoor production systems is to provide better welfare, the presence of straw bedding or pastures allows animals to roam free, graze and root as they desire (Park et al., 2017). Poor environmental stimuli cause pigs to reduce activity and when proper resting areas are not available, it may lead to abnormal stereotypic behaviours and aggression (Olczak et al., 2015). Furthermore, the behaviour of pigs reared outdoors is greatly influenced by weather patterns. To mitigate the impact of weather conditions, most outdoor farms provide shelters for pigs, allowing them to seek cover from the elements (Miao et al., 2004)

Several studies compared the behaviour of outdoor reared pigs to the behaviour of conventional pigs. Outdoor reared piglets were more active and showed a richer behavioural repertoire than indoor-housed piglets, while having no significant differences in production characteristics, like growth rate and weight etc. (Johnson et al., 2001). Nakamura et al. (2011) reported on the behaviours of piglets who were introduced into two different housing systems (indoors and outdoors). The outdoor reared piglets explored more and played more. In contrast, piglets in the indoor system rested more and showed more aggressive behaviours such as ear biting, tail biting, belly nosing etc. Yonezawa et al., (2012) found that the piglets reared in an outdoor environment tended to perform more rooting episodes, as well as total time exploring, than the pigs reared in an indoor environment. All other observed behaviours such as resting, feeding, or social interaction were not different between the two systems. The authors suggested that allowing piglets to live in a free-range piggery might better provide their behavioural needs and demands. In another study done by Tozawa et al. (2016), comparing fattener pig behaviour in intensive and outdoor pasture systems, found that the pigs in outdoor pasture systems expressed more foraging and exploratory behaviours and less resting than the pigs in intensive systems. Furthermore, the frequency of disturbing behaviours was high in intensive pigs compared to outdoor pigs. Guy et al. (2002) who compared three housing systems (outdoor, straw yard and fully slatted indoor) observed the outdoor pigs spending the majority of the time inside the hut and rooting, chewing the floor surrounding and moving around when they were active in the context of UK environment. The indoor pigs spent significantly less time walking or running and spent more time lying inactive. In terms of tail biting behaviour, it was significantly higher in fully slatted (indoor) pens followed by straw yard. No tail biting occurrence was recorded in outdoor paddocks.

Tail biting is a behaviour performed by pigs, which is deemed as abnormal as it is not present in wild boars or other peccarids. This behaviour is mainly observed in indoor environments with high stocking densities, lack of substrate, poor ventilation, deficiencies in feed quality and or accessibility, or poor health (Hansson et al., 2000; Ludwiczak et al., 2021). However, Walker & Bilkei (2006) reported the occurrence of tail biting in outdoor production systems in Croatia. This study was done in winter and the authors suggested that, even though the outdoor reared pigs had better conditions in terms of space and stocking density, other factors such as genetics, respiratory problems, possible dietary inadequacies, and general rooting in muddy pastures might have contributed to the occurrence of tail biting. Similarly, in a Swedish study (Hansson et al., 2000), comparing organic and intensive pigs, they found evidence of tail biting, though highly significantly lower than in intensive reared pigs.

1.3.2 Lesions in outdoor production

Domestic pigs cohabit in small, genetically related matriarchal groups and aggression between pigs is rare outside the mating season and this is a common feature in pigs housed in extensive enclosures (Turner et al., 2006; Stolba and Wood-Gush, 1989). Aggression induced lesions on the skin are correlated with the behaviour of the animal. Skin lesions observed on the front body parts reflect the high frequency of fighting among each other in the pen, however lesions in the middle part of the body do not show a significant relationship with this behaviour. Damage on the rear part of the body indicates an individual being bullied by other individuals (Godyn et al., 2019). Lactating sows housed indoors are susceptible to lesions on the body. Thin sows, wet skin and long periods of recumbency are some of the well-established risk factors (Kilbride et al., 2009). The sows that were most restricted in their crates had significantly increased risk of body injuries, including lesions which occur during the process of standing (direct contact with the surface of the crate) (Kilbride et al., 2009) . An increase in skin lesions influences pig welfare as lesions cause physical pain and can become infected if left untreated (Nakamura et al., 2011).

Tozawa et al. (2016) observed the total number of wounds on the pig body before slaughter in different systems and found that the pigs from intensive systems had a significantly higher number of wounds on the body compared to free range pigs. Nakamura et al. (2011), compared lesions or wounds in pigs reared in outdoor and indoor systems on day 16 and day 29 after introduction to the system and found a greater number of lesions in pigs reared indoors compared to pigs in outdoor systems. Furthermore, a higher number of bloody lesions were found on indoor pigs. Guy et al. (2002) conducted a study in the UK to compare the welfare in three different pig-rearing systems (Outdoor paddocks, Straw yards and fully slatted pens) using several health related criteria (stomach ulceration, body damage, bursitis score, mortality and morbidity etc.). They found significantly higher bursitis (inflammation of bursa) and injury scores in pigs that were finished in a slatted floor system. Hansson et al. (2000) assessed the lesions from organic and conventional pig carcasses in Sweden and found 28% of conventional pig carcasses and 17% of organic pig carcasses had one or more registered lesions. Lesions scores are used in studies to measure the severity of lesions in the body. There are various interpretations and types of scores (Stukenborg et al., 2012; Van Staaveren et al., 2017) but at the baseline, the higher scores indicate poor conditions.

1.3.3 Lameness in outdoor production

Lameness is defined as departure from normal gait, usually accompanied by pain and is caused by a range of conditions (Potterton et al., 2012). Lameness is a welfare issue, particularly in sows, leading to treatments, early culling and ultimately results in economic losses for the farmer (Knage-Rasmussen et al., 2014). Lameness affects all groups of pigs, but sows are more prone to lameness, and lameness is one of the main reasons for culling of sows (Oravainen et al., 2006).

Leg disorders in pigs can be a factor that causes lameness. Leg disorders can be divided into three distinct categories (Jensen & Toft, 2009).

1. Infectious arthritis caused by infectious pathogens
2. Physical injuries such as lesions to the claw and/or leg
3. Various manifestations of osteochondrosis (orthopaedic diseases)

Other than this, bursitis can also be a causal factor of lameness. A bursa is a small fluid filled sack or sack like cavity in places in tissues where friction would otherwise occur (Smith, 1993).

In a study done in Spain and France between 2007 and 2009, in five different pig housing systems including extensive and outdoor systems, Temple et al. (2012) found that the prevalence of moderate and severe bursitis was highest in conventional production systems, whereas the lowest prevalence was in the Mallorcan black pig extensive system. Etterlin et al. (2014) hypothesised that outdoor free-range pigs are more affected by osteochondrosis than intensively reared pigs. During their study, they found that although significantly higher number of pigs had more numerous and more severe osteochodriosis lesions, the housing group did not have a significant impact on gait score thus not supporting the hypothesis of more lameness in free-range pigs. Furthermore, they found a higher prevalence of osteochondrosis in the hock joints and elbow joints with a larger proportion of the free-ranged pigs having moderate or severe lesions and higher condemnation of hocks at slaughter plants. A study done by Hansson et al., (2000), using organic and intensive reared pig carcasses, found significantly higher cases of joint diseases such as arthritis and arthrosis from organic systems, suggesting higher cases of potential lameness. Leeb et al. (2019) assessed pig welfare among organic pig farms across Europe and found that organic sows raised indoors were affected by lameness, whereas sows kept outdoors and a combination of indoor and outdoor, showed lower levels of lameness. Knage-Rasmussen et al. (2014) found a lower prevalence of lameness in organic sow herds compared to conventional sow herds in Denmark. Furthermore, they found that the prevalence of lameness was lower in the winter/spring season.

1.3.4 Ecto-parasites in outdoor production

A parasite is an organism which lives a considerable portion of their lives in (endo-parasites) or on (ecto-parasites) another kind of organism, the host (Taylor et al., 2016). Two types of parasites can be described based on their life cycle. The obligate parasites are entirely dependent upon a specific parasite in order to complete their life cycle and a facultative parasite is an organism which can complete the life cycle independently from the host (Taylor et al., 2016). Parasites can affect the production potential of animals, and affect the average daily weight gain, decrease the weight during weaning, which causes an alteration in food conversion indices, thus increasing the time required before slaughter and further consequences such as low litter size, lack of sexual activity and poor viability of suckling pigs (Lawlor & Lynch, 2007; Mendoza-Gómez et al., 2015; Popiołek et al., 2009). Furthermore, pigs can be epizootically important vectors and reservoirs of parasites, posing a health risk to humans and other animals (Popiołek et al., 2009) and reflecting a One Health issue.

Ecto-parasites live mainly on the skin of the animal and feed off the host. The most common ecto-parasites that affect pigs are mites and lice with the main species being *Sarcoptes scabiei* and *Heamatopinus suis,* respectively (Damriyasa et al., 2004). *Sarcoptes scabiei* causes Sarcoptic mange, a skin disease that can significantly reduce production efficiency in pigs (Taylor et al., 2016).

Haematopinus suis (Hog louse) is the only lice species present in pigs. *H. suis* is relatively large, greyish brown louse with brown and black markings, and measures 5 – 6 mm in length (Taylor et al., 2016) . *H. suis* is the largest blood sucking louse found among domestic animals. *H. suis* can infest pigs at any age, and pigs kept outdoors and/or with poor body condition are more susceptible (Taylor et al., 2016). Low intensity infection is quite common and causes mild irritation. Heavy infestation leads to pigs being restless and can result in skin damage due to scratching (Taylor et al., 2016)

A study by (Damriyasa et al., 2004), in German pig farms, found that 2.5% of the pigs assessed (425 pigs) were infected with *H. suis*. David and Williams (1986) compared hog louse infested pigs with non-infested pigs. They found that the infested pigs were less active compared to non-infested pigs, but there were no differences in blood parameters and feed efficiency. Leeb et al. (2019) observed ecto-parasites in organic pig farms (indoor, outdoor, and indoor with an outdoor run) across Europe and found that 27% of indoor, 10% of outdoor and 26% of indoor with an outdoor run farms had ecto–parasites. They concluded that this low number may be due to the routine treatment schedule against ecto – parasites.

1.3.5 Gastro – intestinal parasites of pigs

The most common endo-parasites that infect the pigs are of gastrointestinal origin and consist of helminths and protozoa. Twenty species of helminths are recorded in domestic pigs while

5 – 10 species coexist together in wild boars, but can occur in domestic pigs when they are reared in an outdoor pasture (Nansen & Roepstorff, 1999). The most common helminth parasites in temperate countries include *Ascaris suum*, *Trichuris suis* and *Oesophagostomum* spp. (Roepstorff et al., 2011a).

The most important gastro-intestinal protozoa in pigs are coccidiosis-causing organisms such as *Eimeria* spp., which are commonly found in adult pigs and *Isospora suis*, which can be commonly found in young piglets, with a worldwide distribution (Kagira et al., 2010). *Balantidium coli* is another protozoon that can infect humans and pigs, with prevalence of between 20 – 100% reported in pigs in different countries (Kagira et al., 2010; Solaymani-Mohammadi & Petri, 2006). There are 13 species of *Eimeria* and eight species are common which are *E. delibiecki, E. neodebliecki, E. perminuta, E. polita, E. porci, E. scabra, E. spinosa, and E. suis* (Daugschies et al., 1999). *Eimeria* spp., along with *Isospora suis*, causes coccidiosis in pigs, especially in piglets. Infections from *Eimeria* spp. occur in the older pigs and even though they are asymptomatic, cases of diarrhoea, weight loss and fatalities are recorded (Taylor et al., 2016).

Suborder Stronglida is a suborder of the phylum Nematoda, which comprises many helminths, such as *Hyostrongylus* spp. and *Oesophagostomum* spp. that are important parasites in the pigs. These parasites are not often associated with clinical disease, however severe infections can cause loss of body weight, poor feed conversion, vomiting, anaemia and occasional diarrhoea (Taylor et al., 2016). *Ascaris suum* is the largest nematode species that occurs in pigs. Heavy infections can cause loss of weight in pigs and pneumonia can occur in younger piglets due to migration of larvae in the lungs (Taylor et al., 2016). *Trichuris suis* is a nematode species, individuals of which are about 3 -5 cm long and whitish colour. The clinical significance of this genus is negligible, but heavy infection may lead to bloody watery diarrhoea (Taylor et al., 2016). Development and survival of pig helminths depend on several biotic and abiotic factors and management practices determine the transmission rate and the risk of economic losses caused by parasitism (Nansen & Roepstorff, 1999).

1.3.5.1 Gastro – intestinal parasites in outdoor farms

Outdoor pig farming poses a higher risk of endo-parasitic invasion due to the favourable conditions for development and survival of parasites in the surrounding environment (Salajpal et al., 2013). Indoor production systems, even where the farms have poor hygiene, have the edge when it comes to worms with indirect life cycles, as the intermediate hosts are missing from the indoor environment (Nansen & Roepstorff, 1999). Parasite numbers in outdoor produced pigs are often high (Carstensen et al., 2002; Roepstorff et al., 2011). In the case of helminths, *Oesophagostomum* spp. do not seem likely to build up to unacceptable levels, presumably because the free living larvae survive poorly during the warm dry weather conditions of southern Europe and the cold winters in northern Europe (Roepstorff & Murrell, 1997; Thomsen et al., 2001). However, *A. suum* and *T. suis* are transmitted by eggs, and the eggs are highly resistant to environmental factors, thus surviving for long periods in the soil (Roepstorff et al., 2011a). In the northern European context, *Oesophagastomum* spp. and *A. suum* are capable of transmitting in indoor production systems, but the former species is more sensitive to intensive management conditions (Nansen & Roepstorff, 1999) .

A number of studies were conducted in Europe for gastro – intestinal parasites in outdoor reared pigs. Baumgartner et al., (2003) provided an overview of the organic pig production in Austria in terms of health and welfare of animals. They conducted faecal sample analysis and found that 75% of the herds were affected with parasites. *Oesophagostomum* spp. was the most common parasite found in sow units and *A. suum* was the most common parasite found in finishing herds. Delsart *et al.* (2022) assessed 70 alternative (outdoor/organic) farms in France for the prevalence of parasites in faeces and blood. Only five farms out of seventy had no coccidian or helminth eggs. Coccidia were found in 79% of the farms and helminth prevalence for *Oesophagostomum* spp., *Ascaris suum* and *Trichuris suis* was 47%, 16% and 36% of the farms respectively. (Rousing, 2011) conducted an epidemiological survey in organic pig farms across several countries in Europe. They found that *A. suum* was the most common parasite found in farms across Europe, with strongyles present in high levels. *T. suis* was detected in lower levels and coccidia, mainly *Eimeria* spp. were also highly prevalent.

Seasonality has an effect on prevalence and burden of parasites in pigs. Carstensen et al. (2002) assessed nine organic pig herds in Denmark between March and October 1999 and found that a significantly higher prevalence in *A. suum* numbers in October compared with earlier months. *Oesophagostomum* spp. had significantly higher prevalence in August compared with other periods. Parasite contamination can lead to economic losses and can reduce carcass quality (Jemal & Kebede, 2016). Jolie *et al.* (1998) examined liver and respiratory tracts of indoor and outdoor reared pigs and scored liver for milk spots and found higher liver scores (poor) and respiratory tract lesions in outdoor reared pigs, implying the damage done by ascarid larvae migration. In contrast, no lesions or white spots were found in indoor reared pigs.

1.3.5.2 Control of gastro – intestinal parasites in outdoor farms

The control of gastro - intestinal nematode infections, in the past and still today, is primarily based on preventive or curative use of chemotherapeutics. Chemical treatments are simple and cheap and used as both prophylactic and therapeutic against helminths. However, they have several drawbacks, like impairing the development of natural immunity, potential drug residues in food products and in the environment (Thamsborg et al.,, 1999; Maqbool *et al.*, 2017). Furthermore, (Jolie et al., 1998) indicated that anthelmintic protocols were not effective in pigs with heavy parasite infestation, due to continuous exposure to *A. suum*. As a result, research interest is shifting to finding alternative methods to control parasites.

There is interest in using plants as a natural anthelmintic in treating pigs in an organic environment. Băieş et al. (2022a) found that plant extracts from *Allium sativum, Artemisia absinthium, Cucurbita pepo* and *Satureja hotensis* have strong anthelmintic properties and can be used to treat against *A. suum* infestation. Satrija et al. (1994) investigated the natural anthelmintic activity of papaya (*Carica papaya*) in pigs naturally infected with *A. suum* and found a post mortem worm count reduction in all groups and proposed the possibility of using papaya extract as a traditional medicine. Lans et al. (2007) documented a list of plants that are used by farmers and alternative medicine practitioners to treat animals including pigs in Canada. Of the documented plants, over 30 of them had mid to high-level validation for ethnoveterinary uses.

Pasture rotation is an important factor in controlling parasites in outdoor production (Lindgren et al., 2020). On pasture, parasite eggs from *Oesophaghastomum* spp. and *H. rubidus* can survive for a maximum of one year and even pastures heavily contaminated in autumn may be completely clean by the following spring (Thamsborg & Roepstorff, 2003). Lindgren et al. (2020) reported that in Sweden, short rotation intervals were used to address land limitations and reduce the workload for dry sows; however, longer rotation intervals were associated with lower accumulation of parasite eggs. Carstensen et al. (2002) compared helminth infections in conventional and organic pig herds in Denmark and found organic pigs having higher rates of infection compared to conventional systems. They found positive effects in pasture rotation on reducing parasite burden along with good hygiene practices. The frequency of rotation can be subject to the condition of the pasture of the particular farm.

Nose ringing of pigs is considered as a solution for excessive rooting, thus one can hypothesize that it could reduce the intake of parasitic eggs from the soil. (Mejer et al., 2000) assessed the relationship between nose ringing and parasite transmission, particularly in *Oesophagostomum* spp. However, they were not able to find a significant relationship between the effect of nose ringing and parasite transmission. Furthermore, nose ringing can lead to reduced welfare of pigs, since, as mentioned previously, rooting is considered a behavioural need of the animal and suppressing it could hinder pig welfare (Horrell et al., 2023).

1.4 Welfare of the environment in outdoor pig production

The world livestock sector is contributing 14.5% of global greenhouse gas emissions and pigs account for 9% of the total emissions from livestock (Rudolph et al., 2018). Livestock production can exert severe impacts on soil, water and air quality due to the related emissions. Nitrogen in livestock excreta is a source of atmospheric nitrous oxide and can cause nitrate leaching in the soil (Erikson et al., 2020). Backyard pig systems compared to conventional systems have relatively high manure emissions caused by relatively high volatile solids and nitrogen excretion per kg of pig meat produced (Gerber et al., 2013).

Pigs raised in outdoor systems are able to explore and manipulate the environment around them. Keeping pigs in pastures year-round causes significant risks in terms of nitrate leaching, ammonia emissions and nutrient losses (Jakobsen et al., 2015). Rudolph et al. (2018) compared three different organic pig-farming systems (indoor, partly outdoor and outdoor) in Europe by conducting life cycle assessments. They found that the acidification potential was high in indoor farms, while the eutrophication potential was high in outdoor farms. They deduced that the phosphates, arising from the feed consumptions and emissions on pasture, were the reason for higher eutrophication potential. In their study using three outdoor pig farms in Denmark, Erikson et al. (2020) concluded that a high amount of surplus nitrogen was lost to the environment by outdoor pig production systems. Furthermore, they emphasized the need for the necessary development of increasing nitrogen efficiency in outdoor pig production. In another study conducted in Denmark, Halberg et al. (2010) concluded that indoor conventional systems had better overall economic and environmental performance, compared with systems where the pigs are on grassland and housed in huts (free range). Even though the greenhouse gas emissions were lower in organic systems, compared with conventional system, eutrophication and acidification per pig was 21 – 65% higher in the organic systems.

1.4.1 Soil quality

Pigs have access to the soil in the outdoor environment, and foraging and rooting in the soil may increase the potential for soil erosion and leeching (Horta et al., 2022). Furthermore, overgrazing may lead to soil degradation. The negative effects of overgrazing can be caused directly by trampling and indirectly by reducing the vegetation cover (Enne et al., 1998). According to model data analyzed by (Horta et al. (2022), outdoor pig production systems in Portugal have a 96% probability of severe to extremely severe soil erosion risk. Additionally, 85% of these systems were at moderate risk for groundwater pollution vulnerability, with 15% classified as high risk.

When pigs are kept in the same area without rotation, and due to pigs' nature of defecating and urinating at a preferred area in the paddock, the distribution of manure around the paddock is not consistent, thus leading to differences in nutrient availability in different areas of the paddock. The study done by Saloman et al. (2007) in Sweden, comparing two outdoor systems (mobile and stationary), revealed significantly higher amounts of plant available P in defecation areas compared to other areas.

Watson et al. (2003) also found that the spatial variability of nutrients in the soil varied significantly across different areas in the paddock and the amount of N and P received in preferred areas by pigs were sufficient to saturate the soil and represented a significant environmental risk. Furthermore, they recommended precision-farming approaches for outdoor pig farms where planning of fertiliser application could be better utilized.

It is suggested that outdoor pig fattening systems should assign a high priority to nutrient input and its distribution within the farming system (Quintern & Sundrum, 2006), This study in Germany proposed strategies to reduce the leaching of N;

1. Changing the N content of the concentrate to the different stages of the development of pigs
2. Limit the amount of concentrate

3. Consider available forage from arable land to reduce the ratio of concentrate
4. Avoid fodder loss by using fodder troughs into which pigs cannot step
5. Decrease soil nutrient content by increasing nutrient uptake when integrating outdoor pig keeping into crop rotation

Bondi et al. (2015) explained the ecological damage after pigs were introduced to two forest systems in Italy. There were direct effects from the trampling, such as compaction and soil organic matter losses and indirectly, reduced soil chemical fertility by removal of vegetation. These effects worsened when the density of animals increased. Increased damage was also noted in areas of increased slope.

Williams et al. (2006) conducted a study in Berkshire, England to assess the nitrate leaching and residual nitrogen supply following outdoor pig farming. They found large nitrate losses in the first winter following outdoor farming, with no residual available N benefits if crops are planted afterwards in the same land. They suggested developing improved management practices, to reduce N leaching losses during stocking and after stocking of pigs. Furthermore, they proposed strategies to improve the retention of vegetative cover for plant N uptake, such as establishing rhizominous grass varieties, which can be more 'resistant' to the rooting habits of pigs and using rotational stocking to allow grass swards to recover.

1.4.2 Biodiversity

Outdoor pig farmers often rear native breeds or rare breeds in their farms, as these breeds are capable of withstanding the elements from the open environment despite their slow growth rate (Bondoc, 2015). However, by rearing these native and rare breeds, the farmers are inadvertently or intentionally contributing to the preservation of genetic material of these native breeds and thus, enhancing biodiversity among pig populations. Kasprzyk and Walenia (2023) documented native pig breeds in Europe, which are kept in extensive systems in pasture or woodlands, where they documented more than 30 breeds based on their population size and the place of origin.

A unique example of outdoor pigs contributing to the preservation of biodiversity in an ecosystem is the "*Dehesa*" system in Spain and Portugal. The farmers around south western Spain and Portugal rear Iberian pigs in Cork Oak (*Quercus suber*) forests there. The pigs forage and eat the acorns from oak and help to maintain the system by contributing to the spread of trees. The system also provides a habitat for Iberian Lynx (*Lynx pardinus*) (IUCN status - vulnerable) and other wildlife species. Estevez et al. (2012) has described the "*Dehesa*" in extensive detail and emphasizes the importance of maintaining low stocking rates of pigs to ensure the sustainability of the system.

Outdoor pigs are susceptible to diseases and rearing pigs outdoor can increase the accessibility of the pathogens from the wild population. De Lucia et al. (2018) assessed pig faeces and bird faeces in outdoor farms in Italy and found a possible cyclical dissemination of *Salmonella* between pigs and wild birds. Leirs et al. (2004) conducted a survey on small mammals (rodents) found in outdoor pig farms in Norway and recorded over eleven species. Considering rats to be pests and carriers of pathogens, they emphasised the importance of controlling rodents, but at the same time, these farms contributed to biodiversity by hosting large number of a range of species of small rodents.

Studies that directly assess biodiversity in outdoor pig farming are scarce, however, there are bio – diversity assessments. Rockly et al. (2021) assessed the biodiversity across pig farms across Europe and 51% of a biodiversity score was across a mixture of organic and conventional farms. There are studies done using feral pig populations around the world as the rooting behaviour is similar in both pig populations. Wehr et al. (2019) assessed soil bacterial biodiversity in soils disturbed by feral pigs living in a tropical montane rainforest in the island of Hawaii. They found that removal of soil by pigs increased the diversity of soil bacteria, and soil porosity, calcium and potassium were also positively correlated with diversity. Similarly, Parkes et al. (2015) measured the ecological impact of feral pigs in coniferous forests in New Zealand and they found a tendency of disturbed soil having higher ratios of fungi to bacteria compared to undisturbed soils. Cole et al. (2012) measured the plant coverage and diversity in tropical montane rain forests in the island of Hawaii, where feral pig populations were present. There was a significant increase in the stem density of young tree ferns in pig free sites in comparison to pig present sites. However, non-native invasive shrub coverage also had a five – fold increase in pig free sites.

1.5 Outdoor production systems, well-being, and quality of life of the farmer

The farmer is an important factor in farming, as the decision making process of the farm is entirely dependent on the farmer. Farming is considered a stressful occupation (McGregor et al., 1995; Proctor & Hopkins, 2023). Stressors of farming includes financial difficulties, time limitations, paperwork and unfavourable weather (McGregor et al., 1995). More recently, overwork, labour shortage, changing government regulations and media criticism of agriculture are significant contributors to stress (Firth et al., 2007; Ang, 2010).

The relationship between farmer welfare and animal welfare is highly correlated (Hemsworth et al., 2000). Stockmanship is the single most important influence on farm animal welfare. Hemsworth et al. (2000) studied the relationship between the behavioural attitudes of dairy stockmen and the milk production traits of dairy cows and found that reducing the fear responses of cows to humans can improve the productivity of cows. Villettaz Robichaud et al. (2019) studied the association between welfare indicators and productivity and profitability in Canadian dairy producers and found that improved cow comfort and welfare can increase the herd productivity and profitability. Nevertheless, studies on the relationship between the well-being of farmer and welfare of animal are limited. Hansen & Østerås (2019) examined this in the Norwegian dairy context and found that high farmer occupational well-being and low level of stress have a direct positive association with animal welfare indicators. Conversely, low occupational well-being and a high level of stress are negatively associated with animal welfare.

Studies on the well-being of farmers in pig farms are rare and most studies have focused on the farmer attitude towards animal welfare in the organic environment. Farmers who are engaged in outdoor pig farming have a better understanding of the welfare of the animals as the following studies suggest. Van Huik and Bock (2007) assessed the attitudes of Dutch pig farmers to welfare schemes and all of the farmers operating in the specific animal welfare scheme did so primarily for ideological motives, believing that the specific production method provided pigs with a better life. Früh et al., 2015) interviewed 74 organic pig farms in 8 countries across Europe and evaluated the farmer satisfaction with the status quo. Almost all of the outdoor organic pig farmers were satisfied (50% (6) very satisfied; 50% (6) satisfied) with the welfare of the animals but were less satisfied with the production level (34% satisfied; 66% neutral). All of the farmers understood the need to improve health and welfare of animals.

Kling-Eveillard et al. (2007) interviewed farmers with different welfare quality assurance schemes in France, which included outdoor and organic farmers. The farmers had at least a bachelor’s degree level of education. The majority had chosen the outdoor system out of a passion for this type of farming and some of them chose the profession for the environment and that they could work outdoors. Positive aspects of farming included enabling animals to be in natural conditions as well as animal comfort. The negative aspects of farming, as far as they were concerned, were the large amount of time and effort required. The constraints included lack of technical and financial support towards outdoor farming. They considered outdoor systems had a better public image and supported the idea of communication campaigns for their production system. Brajon et al. (2024) discussed the barriers and drivers of farmers in providing outdoor access in pig farming systems in France using structured interviews. The farmers found that the work involved in being outdoors is particularly arduous but they were satisfied with being in contact with the nature and seeing animals in a more complex environment. A large majority of farmers managing an outdoor system had an issue of lack of support and the farmers raised concerns about the welfare of the animals raised outdoors regarding climate hazards and the risk of zoonoses.

In conclusion, there is a growing demand for alternative pig systems, and a promising growth due to consumer concern on animal welfare. Different studies have been done on the welfare of the animals, the environment where the animals has been reared and to a lesser extent, the well-being of the farmers. Animal welfare is considered to be in better condition in terms of behaviour and lesions, however in terms of lameness and parasites, outdoor pig systems tend to be higher than that of conventional system. Environment wise, the study findings indicated mostly negative impacts; however, there can be positive impact on the microflora. Farmers of the alternative systems have a lack of farming knowledge and strict government regulations also pose difficulties. In the Irish context, due to the scarcity of literature and materials, studies about outdoor pig systems need to be conducted, and produce data on this industry to improve the present situation.

Chapter 02

Effect of the season and age on the welfare of the pigs and the environment of Irish outdoor farms: a 'One Welfare' approach

2.0 Effect of the season and age on the welfare of the pigs and the environment of Irish outdoor farms: a 'One Welfare' approach

2.1 Effect of the season and age on animal welfare and environment of Irish outdoor pig farms

2.1.1 Abstract

Outdoor pig farming, while limited in scale in Ireland, is gaining attention due to its alignment with growing consumer interest in animal welfare and environmental sustainability. Unlike intensive systems, outdoor farms offer pigs access to soil and vegetation, which encourages natural behaviours like rooting and foraging. However, challenges such as seasonal weather effects and parasite exposure pose unique risks to pig welfare in outdoor systems. In this study, we assessed 446 pigs from 20 Irish outdoor pig farms across two seasonal visits (February–May and July–October 2023) to investigate the impact of seasonality on welfare (body condition score, lameness, lesions, etc.) and environmental quality (soil shear strength and plant diversity) in three distinct areas of the paddock by the usage of the pigs (foraging, defecation, and low impact). Both fatteners and sows/boars were included. Significant seasonal effects were found in some of the animal welfare measures. At the 1st visit there were higher number of pigs with higher lameness scores and external parasites than at the 2nd visit, while at the 2nd visit there were more lesions per pig than at the 1st visit. Sows/boars exhibited a significantly higher incidence of lameness, external parasites and skin lesions compared to fattener pigs. Soil shear strength (delta value) was significantly greater in the foraging area of the paddock on the 1st visit than at the 2nd visit, suggesting greater compaction. Plant diversity declined from the 1st to the 2nd visit. Overall, the majority of the pigs displayed few signs of poor welfare. The results indicated minor seasonal effects most likely due to the changes in the climate. This study provides the first view of the welfare of the pigs and environment on outdoor systems in Ireland at different times of the year.

Keywords – Outdoor pigs, welfare, environment, season

2.1.2 Introduction

An extensive pig production system is one where pigs are allowed to have outdoor access and be in contact with the soil and the plants (Honeyman et al., 2001). Outdoor pig farming has grown in popularity in recent times, in countries such as the United Kingdom, due to concerns over animal welfare and consumer preference (Pun et al., 2024). However, elsewhere it remains relatively small, e.g. in France where the number of alternative farms represents only 5% of the pig farms, and the outdoor farms would be even lower (Delsart et al., 2020).

The concept of One Welfare recognises the interconnections between animal welfare, human wellbeing and the environment (Pinillos et al., 2016). According to the One Welfare concept, human welfare and non-human animal welfare are interconnected, such that poor welfare in livestock production systems is more likely to have negative effects on human welfare as well (Tarazona et al., 2019). The environment is also affected by actions due to the human-animal relationship, most notably in livestock production where there are environmental concerns arising from greenhouse gas emissions from animal husbandry (Tarazona et al., 2019) . One Welfare concept looks at all three components and provides a holistic understanding of welfare issues.

Pigs reared in outdoor systems show a rich behavioural repertoire (rooting, exploring, foraging) compared to pigs reared indoors, where there is a higher frequency of disturbed behaviour and inactivity (Guy et al., 2002; Tozawa et al., 2016; Yonezawa et al., 2012). Lameness is also less of a health problem in outdoor-reared pigs compared to those in conventional indoor systems (Hansson et al., 2000; Knage-Rasmussen et al., 2014; Temple et al., 2012). The presence of external parasites and tail lesions in outdoor and organic conditions are low across Europe (Leeb et al., 2019; Walker & Bilkei, 2006). Nevertheless, pig behaviour means that the quality of the environment where the pigs are reared can deteriorate over time, with rooting behaviour and defecation increasing the potential for soil erosion and leaching (Horta et al., 2022).

The climatic environment is among the crucial factors that affects the production of farm animals and adverse effects of temperature, relative humidity and other climate factors can cause thermal stress, resulting in impaired health and welfare (Renaudeau et al., 2012; Čobanović et al., 2020). This can be especially important in outdoor pig rearing as the pigs are exposed to the effects of weather. Several studies show seasonal differences in terms of various welfare-related parameters such as lameness, lesions and external parasites (Foata et al., 2006; Knage-Rasmussen et al., 2014; Prunier et al., 2013).

Irish outdoor pig farming is a small-scale industry, with an average number of only 7 sows and gilts, 2 boars, 18 grower pigs and 17 piglets at any time of the year per farm (Menant et al., 2023 [and in preparation]). The main breeds reared are Duroc, Oxford Sandy and Black, Tamworth and Gloucester Old Spot. They are reared either in agro – forestry systems or pastures or in a mixture of both. Literature on Irish outdoor pig production systems is relatively scarce hence, this study aimed to provide an overview of the status of animal and environmental welfare in outdoor pig farms in Ireland across the year.

The objectives of this study were:

- To investigate the welfare of the pigs reared in outdoor farms in Ireland and identify any seasonal and age related trends
- To evaluate the environment in the outdoor farms in Ireland and to assess seasonal trends in selected environmental measures

2.1.3 Materials and methods

2.1.3.1 Farm selection and animals

The farms were selected using a survey distributed via various channels (Menant et al., 2023). From the farms contacted through the survey, 20 farms gave their consent for a visit. These farms were visited during two time periods; the first visit was between February and May 2023 (late winter to early spring) and the second visit was between July and October 2023 (summer to early autumn). Nineteen farms were visited in the first time period and 17 farms during the second time period. Farms were located across a range of locations in Ireland including Northern Ireland (see Fig. 2.1 and Table 2.1). All of the twenty farms had outdoor access for the pigs when the assessments were conducted. The farms included organic and non – organic farm systems and the farms included animals reared in pasture or in an agro – forestry system or a mixture of both. All of the animals assessed were more than 3 months old. Lactating sows and piglets were excluded from the study due to practical issues in assessing these animals (Table 2.1).

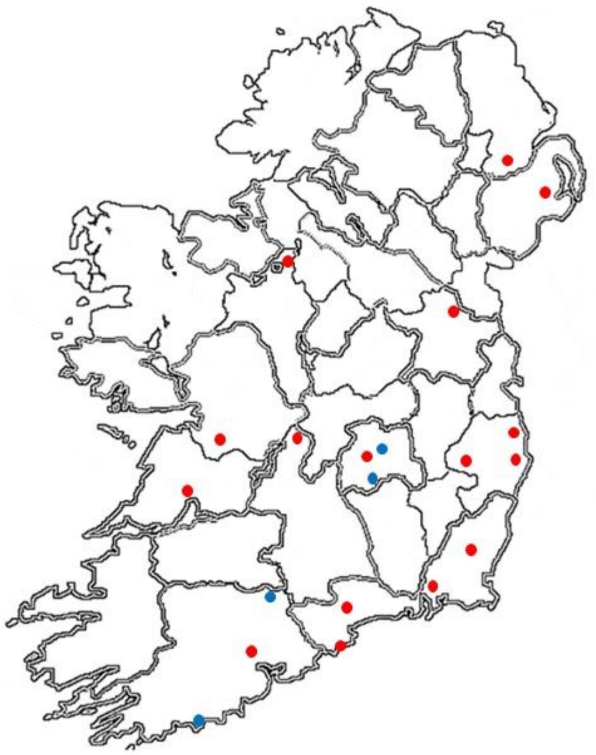

Figure 2.1 – Locations of the pig farms in Ireland visited during the two visits. Farms that were visited once only are in blue

Table 2.1 – Characteristics of the farms visited

Farm no	County	Month of visit(1st visit, 2nd visit)	Breeds	Paddock area (ha)	No of sows	No of Boars	No of fatteners
1	Cork	March, August	Duroc, GOS , OSB, Tamworth	3	25	3	24
2	Waterford	March, September	Duroc, OSB	1	3	1	14
3	Clare	April, October	Duroc, Hampshire, Large Black, OSB	2	2	0	50
4	Waterford	May, September	Berkshire, OSB, Tamworth	10	5	1	40
5	Wexford	April, October	Duroc, OSB	1	3	0	4
6	Laois	March, August	British saddleback, Duroc, GOS, Hampshire	1	15	1	50
7	Wicklow	March, September	OSB, Oxford cross breeds	6	3	0	12
8	Wicklow		OSB	323	22	6	100
9	Wexford	February, July	OSB	2	4	1	15
10	Wicklow	February, August	Tamworth, Vietnamese pot bellied	8	2	2	20
11	Tipperary	March, August	Tamworth	40	4	1	14
12	Louth	April, September	Duroc, OSB, Tamworth	10	9	1	12
13	Down	December, July	Large Black, Midddle White, Tamworth	2	10	2	25
14	Laois	February	Duroc, British Saddleback	2	2	1	10
15	Cork	February	Kune Kune, Idaho pasture pigs	1	11	0	4
16	Laois	March	Duroc, GOS, Landrace	11	4	1	20
17	Antrim	April, September	Mangalista	1	4	1	20
18	Sligo	April, September	Berkshire, Duroc, Large White	1	0	0	8
19	Galway	December, July	Landrace, Large White	7	6	2	24
20	Cork	July	Duroc, OSB	0.02	2	0	5
		Average		**21.6**	**6.8**	**1.2**	**23.6**

OSB – Oxford Sandy and Black, GOS –Glucester Old Spot

2.1.3.2 Animal welfare assessment

Animals were assessed for their welfare using a combination of indicators. A total of 445 animals from the 20 farms were investigated: 222 animals during the 1st visit (19 farms) and 223 animals during the 2nd visit (17 farms). Animals were observed by one observer and scored based on a range of welfare parameters. Age, sex and breed of each animal was also recorded. The welfare parameters were as follows:

2.1.3.2.1 Body condition score (BCS)

The pig was observed and the body condition score of each animal was recorded using a 1 – 5 score method (Farm animal welfare advisory council, 2017) (Table 2.2) and see Fig. 2.2.

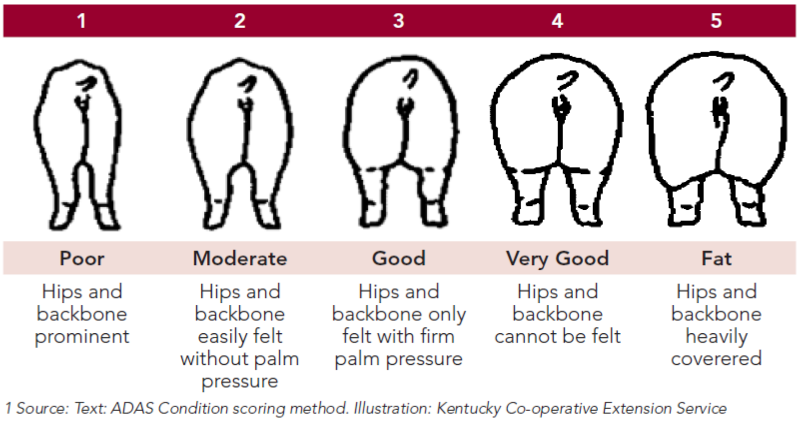

Figure 2.2 – The scale of BCS and the interpretation for each score

2.1.3.2.2 Lameness

Each pig was observed for at least 30 seconds in motion and lameness was recorded using a 0 – 5 scale scoring method. The animal was scored according to their gait (Table 2.2).

2.1.3.2.3 Skin lesions

Each animal was examined for lesions on the head, neck, shoulders, back, rump, front and back legs. The number of old lesions and fresh lesions were recorded separately for each area. The total number of lesions on the body was recorded for both old and new lesions.

2.1.3.2.4 Ear lesions

The ears of the animal were observed and scored according to a scoring scale (0 – 4 scale) developed (Table 2.2). Both ears were observed and scored separately. The size of the ear and ear loss was also recorded (Full, three –quarter, half, quarter and almost non-existent).

2.1.3.2.5 Tail lesions

The tail of each animal was observed and scored using a 0 – 4 point scale (Table 2.2). Details on tail docking were also recorded. The size of the tail was recorded separately (complete, three quarter, half, quarter and no tail).

2.1.3.2.5 Tear stains

Both eyes of the animal were observed for tear stains and recorded and scored accordingly. Left and right eyes were scored separately to observe the relationship with the brain function of tearing (Telkänranta et al., 2016) (Table 2.2).

2.1.3.2.6 Presence of external parasites

The skin of the animal was observed for presence of external parasites. A pig was recorded as having a parasite being present if an adult or eggs were found on the skin. Presence of eggs was recorded as parasites present (1) and absent (0).

2.1.3.2.7 Snout shape and nasal discharge

The snout was observed and differentiated into three categories (straight, curly and twisted on side). The colour of nasal discharge was also recorded (no discharge, white and bloody).

Table 2.2 – Scales and the interpretation of the BCS, lameness score, tail lesion score, ear lesion score and tear staining score

Score	Interpretation
BCS	
1	Poor – Hips and backbone prominent
2	Moderate – Hips and backbone easily felt without palm pressure
3	Good – Hips and backbone only felt with firm palm pressure
4	Very good – Hips and backbone cannot be felt
5	Fat – Hips and backbone heavily covered
Lameness cont.	
0	Even strides
1	Abnormal stride length, movement no longer fluent
2	Uneven posture
3	Uneven posture, will not bear weight on affected limb on standing posture

4	Unwilling to leave familiar environment, affected limb elevated off the floor standing posture and in movement
5	Cannot stand up/move
Tail lesion score	
0	No lesions
1	Old, dried up wound in the tail
2	Fresh, bloody wound present in the tail
3	Swollen, and bite wound present in the tail
4	Treated wound with tail loss
Ear lesion score	
0	No evidence of ear lesions
1	Evidence of minor superficial puncture wounds and abrasions, with no appearance of blood
2	Evidence of blood and/or fresh bloody scabs associated with lesions
3	More extensive progression of lesions, with swollen ears
4	Necrotic lesions associated with fresh blood, bloody scabs, potentially pus
Tear stain score	
0	No sign of any staining
1	Staining is present in approximately <50% of total eye area
2	Staining is present in approximately 50 – 100% of total eye area
3	Staining is ≥ 100 of total eye area and extends into a long line

2.1.3.3 Environmental measurements

2.1.3.3.1 Soil compaction (shear strength)

Soil compaction was recorded on 14 farms during the 1st visit and on 17 farms during the 2nd visit. The soil compaction was measured in terms of the shear strength of the soil. The shear strength was measured using the shear vane technique. A field vane tester with the small vane size (16 × 32 mm) was used. As pigs do not use the area of a paddock uniformly, paddocks were divided into three areas based on functionality. Areas were; low impact area, foraging area and defecation area. An additional area outside the paddock was measured as the baseline measurement for compaction representing an area without the influence of pigs. After clearing any grasses away from the soil surface, the vane tester was applied 70 to 80 mm into the soil. The graduated scale was set to "0" before using. Once the vane was in the appropriate depth, the handle of the vane was turned clockwise with a constant speed until the scale stopped moving. The value on the scale was then recorded. Two measurements per each sample point was recorded and three replicates per each area was recorded. The shear strength value (kPa) was obtained by multiplying the value by 2 in each recording as the small vane was used. Average shear strength value (kPa) was calculated from the three replicates. A delta value (Δvalue) was obtained by subtracting the shear strength value of the sample area within the paddock from the shear value in the area with no pigs as a comparison value to get an idea about the compaction of the sample area to outside area. Soil type was not identified and during some farm visits, paddocks was different from the 1st visit to the 2nd visit.

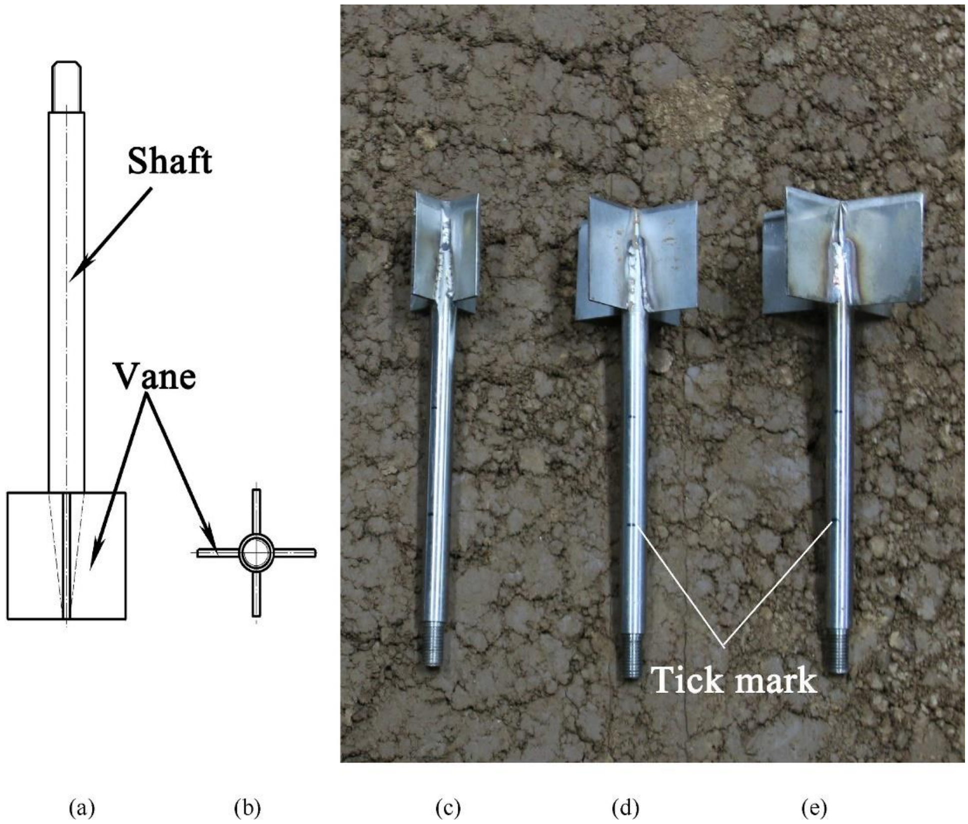

Figure 2.3 – Shear vane probes used to obtain the shear strength value (He et al., 2018) (a), (b), (c), (d) and (e) represent different vanes

2.1.3.3.2 Number of plants and the coverage of plants

A quadrat (1m × 1m) was used to count the number of different plants and to measure the coverage of the plants in each of the areas. Each plant species inside the quadrat was photographed for later identification. Three quadrats measures of plant species were sampled from each area of the paddock (foraging and defecation) and averaged for each area.

The delta value of each area was obtained by subtracting the average number of plants in each area from that in the ‘no pig’ area which was used as the baseline for the study. This measurement was taken to evaluate the plant richness in each area of the paddock compared to the outside area of the paddock.

2.1.3.4 Statistical analysis

2.1.3.4.1 Animal based measurements

All of the statistical analyses were performed using Rstudio software (R core team, 2022). The score based data were analysed using the ordinal (Christensen, 2014) package in Rstudio. Body condition score, lameness score, tail lesion score, ear lesion scores and the tear stain scores were analysed using a cumulative link mixed model (CLMM) with a logit function. Visit and age category were employed as the fixed effects, while paddocks nested within farms were employed as random effects, to describe the hierarchical nature of the data. Emmeans package was used to derive estimated marginal means (emmeans) for further pairwise comparisons.

The presence of parasites was analysed using a generalized linear mixed model (GLMM) using the lme4 package with a binomial response with logit function. Presence of parasite was recorded as a binary variable (1 = present, 0 = absent), with visit and age category as fixed effects and paddocks nested within farms as random effects to account for the hierarchical and clustering effects of farms. Emmeans package was used to derive emmeans for pairwise comparisons.

Lesion counts (fresh lesions, old lesions and sum of all lesions) were analysed using a negative binomial regression model, to account for the overdispersion in the lesion count data. Lesion count was fitted using glm.nb function with MASS package with visit and age categories as functions. Pairwise comparisons were made using the emmeans package.

2.1.3.4.2 Environmental measurements

A linear model was applied to soil shear strength difference in each area in paddock in relation to outside of the paddock, with visit and age category accounted for in the model. Lm function was used to fit the model and further pairwise comparisons were analysed using estimated marginal means using emmeans package. To analyse the seasonal differences and the age category related differences, a Kruskal-Wallis test was used due to the non – normal distribution of the data.

2.1.3 Results

The average weather conditions for the 1st visit was 120.6 mm of rainfall and a temperature of 10.7 °C and for the 2nd visit, rainfall of 162 mm and temperature of 16.4 °C respectively (Met Eirenn, 2023).

2.1.3.1 Body condition score

The number of animals with each body condition score (BCS) are presented in Table 2.3. Of the 222 animals assessed in the first visit, 191 (86%) had a BCS of >3. 223 animals were evaluated during the second visit and 177 (79%) animals had BCS of >3. Of the 126 fattener pigs in the 1st visit 115 (91%) had a good BCS (>3) and with the same number of fatteners evaluated during the second visit, 114 (90%) of animals had good BCS (>3). In addition, 76 (79%) of the 96 sows and boars in the 1st visit and 64 (65%) of the 97 sows and boars in the 2nd visit had BCS of >3.

Table 2.3 – Distribution of body condition score of outdoor reared pigs according to visit and age category

BCS	1st visit		2nd visit	
	Fatteners	Sows and boars	Fatteners	Sows and boars
1	1	0	1	2
2	10	20	11	32
3	87	41	65	39
4	28	35	49	24
5	0	0	0	0

There was no significant difference between the two seasons in terms of BCS. However, there was a significant difference between the fatteners and the sows/ boars ($P < 0.05$), where sows and boars tended to have a higher score compared to fatteners. The pairwise comparison of estimated marginal means revealed that the fatteners and sows/boars had significantly different ($P < 0.05$) BCS in both seasons (Table 2.4).

Table 2.4 – Pairwise comparison of estimated marginal means (emmean) of BCS by age category and visit of the pigs

Age category	1st visit				2nd visit			
	Emmean (BCS)	SE	Estimate	P value	Emmean (BCS)	SE	Estimate	P value
Fatteners	2.71	0.622	-0.946	0.0177	3.08	0.651	-0.946	0.0177
Sows/boars	3.67	0.638			4.03	0.683		

2.1.3.2 Lameness

All of the assessed animals had scores of 0 (no lameness) and 1 (abnormal strides). 14 animals (6%) from the 1st visit and 3 animals (1.3%) from the 2nd visit had a score of 1 (abnormal strides). Five fatteners and 9 sows/boars from the first visit had abnormal strides and only 3 sows/boars from the second visit had abnormal strides (Table 2.5).

Table 2.5 – Distribution of body condition score of pigs according to visit and age category

Lameness score	1st visit		2nd visit	
	Fatteners	Sows/boars	Fatteners	Sows/boars
0	121	87	126	94
1	5	9	0	3

The seasonal effect on the lameness scores was significant ($P < 0.05$), where there were fewer animals with score >0 at the 2nd visit compared to the 1st visit. For the age categories alone, there was no significant difference, however there was a significant difference between fatteners and sows/boars, with sows/boars having higher lameness scores compared to fatteners ($P < 0.05$) (table 2.6). Lameness scores for both fatteners and sow/boars were significantly different ($P < 0.05$) during both visits.

Table 2.6 – Pairwise comparison of log odds for the lameness scores by age category and visit season, with standard error (SE) and P-values

Age category	1st visit				2nd visit			
	Log odds	SE	Estimate	P value	Log odds	SE	Estimate	P value
Fatteners	-4.28	0.840			-6.18	1.142		
Sows/boars	-2.79	0.658	-1.48	0.0343	-4.70	0.954	-1.48	0.0343

2.1.3.3 External parasites

All the external parasites were identified as *Haematopinus suis* (Hog louse). During the 1st visit, 30% pigs had hog lice on their skin. There were 17% of pigs with hog lice at the 2nd visit.

The presence of hog lice was significantly different ($P < 0.05$) during the two visits. Fatteners and sows/boars also had a significantly different ($P < 0.01$) presence of parasites with sows/boars being more prone to hog lice presence compared to fatteners. Pairwise comparisons revealed both season within age categories and age categories within season as significant ($P < 0.05$) (table 2.7).

Table 2.7 - Comparison of log odds for the presence of hog lice by age category and visit season, with standard error (SE) and P-values

Age category	1st visit				2nd visit			
	Log odds	SE	Estimate	P value	Log odds	SE	Estimate	P value
Fatteners	-4.00	1.49			-6.54	1.73		
Sows/boars	-1.89	1.40	-2.11	0.0059	-4.42	1.64	-2.11	0.0059
Visit	Fatteners				Sows/boars			
	Log odds	SE	Estimate	P value	Log odds	SE	Estimate	P value
1st visit	-4.00	1.49			-1.89	1.40		
2nd visit	-6.54	1.73	2.54	0.0230	-4.42	1.64	2.54	0.0230

2.1.3.4 Skin lesions

The total number of pigs with fresh (bloody lesions) on the body was 7% (n = 16) for the 1st visit and 7% (n = 17) for the 2nd visit. In general, the number of sows/boars with body lesions was higher than fatteners (table 2.8).The number of pigs with old lesions for the 1st visit was 71 (32%) and 83 (37%) during the 2nd visit. In the case of old lesions, sows/boars also had a number of higher individuals with lesions (table 2.8).

Table 2.8 – Distribution of fresh and old skin lesion counts of pigs according to visit and age category

Fresh lesion count	1st visit		2nd visit	
	Fatteners	Sows/boars	Fatteners	Sows/boars
0	121	85	119	87
1	3	4	5	7
>2	2	7	2	3
Old lesion count	1st visit		2nd visit	
	Fatteners	Sows/boars	Fatteners	Sows/boars
0	99	52	90	49
1	16	28	14	20
>2	11	16	16	28

The negative binomial model and pairwise comparisons interpreted that the sows/boars had a significantly higher number of fresh skin lesions ($P < 0.01$) compared to fatteners in both seasons. There was no difference in fresh skin lesion count between seasons. The results for the old lesion counts resulted in a significant difference ($P < 0.01$) between visits, with pigs at the 2nd visit having higher old lesion counts, and also the age categories showed a significant difference ($P < 0.001$) with sows/boars having higher old lesion counts than fatteners. The sum of both lesion counts showed a significant difference in the two visits with both fatteners and sows/boars having higher lesions count during the 2nd visit compared to the 1st visit, while sows/boars had higher lesion counts compared to fatteners in both visits.

Table 2.9 - Comparison of log odds for the old lesion counts by age category and visit season, with standard error (SE) and P-values

Age category	1st visit	2nd visit

Old lesions	Log odds	SE	Estimate	P value	Log odds	SE	Estimate	P value
Fatteners	-0.9269	0.168			-0.4397	0.157		
Sows/boars	-0.0401	0.164	-0.887	<0.0001	0.4470	0.157	-0.887	<0.0001
	Fatteners				Sows/boars			
Visit	Log odds	SE	Estimate	P value	Log odds	SE	Estimate	P value
1st visit	-0.9269	0.168			-0.0401	0.164		
2nd visit	-0.4397	0.157	-0.487	0.0090	-0.4470	0.157	-0.487	0.0090

Table 2.10 - Comparison of log odds for the all lesion counts by age category and visit season, with standard error (SE) and P-values

Age category	1st visit				2nd visit			
	Log odds	SE	Estimate	P value	Log odds	SE	Estimate	P value
Fatteners	-0.5584	0.161			-0.1743	0.153		
Sows/boars	0.0333	0.164	-0.592	0.0013	0.4174	0.159	-0.592	0.0013
Visit	Fatteners				Sows/boars			
	Log odds	SE	Estimate	P value	Log odds	SE	Estimate	P value
1st visit	-0.5584	0.168			0.0333	0.164		
2nd visit	-0.1743	0.157	-0.384	0.0369	0.4174	0.157	-0.384	0.0369

2.1.3.5 Tail loss and tail lesions

None of the farms practiced tail docking. The tail size was assessed and 6 (1.3%) boars, which were purchased from other farms had docked tails. The tail sizes were recorded and there were 21 pigs (1st visit – 07 pigs, 2nd visit – 14 pigs) in total in both visits with incomplete tails and/or docked tails.

The highest lesion score observed was 2. Tail lesions ≥1 were present in 6 out of 222 pigs (3%) in the 1st visit and 15 out of 223 pigs (7%) in the 2nd visit. Two pigs from the 1st visit had a lesion score of 2 and 3 pigs from the 2nd visit a lesion score of 2. The statistical analysis revealed a tendency (P= 0.063) of a difference in tail lesion scores between the two visits where pigs at the 2nd visit tended to have higher tail lesion scores compared to pigs at the 1st visit. There was no difference in lesion scores between fatteners and sows/boars. (Table 2.11).

Table 2.11 – Comparison of log odds for the tail lesions for visit season, with standard error (SE) and P-Values

Visit	Fatteners				Sows/boars			
	Log odds	SE	Estimate	P value	Log odds	SE	Estimate	P value
1st visit	-4.68	0.685			-4.42	0.628		
2nd visit	-3.65	0.533	-1.03	0.0629	-3.39	0.498	-1.03	0.0629

2.1.3.6 Ear lesions

Ear loss was recorded at only ¼ of the ear being lost and this was only in 3 pigs for 1st visit and 1 pig for 2nd visit for right ear, and 1 pig from the 1st visit for the left ear. During the 1st visit, 96 pigs (43%) were recorded with a lesion score ≥1 for right ear. In the 2nd visit, this number increased to 104 (47%). For the left ear, 97 pigs (44%) had a lesion score ≥1 in the 1st visit and the 2nd visit number was 93 (42%). No pigs were recorded with ear necrosis (Score 4) for either ear (Table 2.12). According to the analysis, neither the visit season nor the age of the pig had an impact on the ear lesion scores for either ear.

Table 2.12 – Number of pigs (fatteners and sows/boars) in each visit with each ear lesion on the left and right hand side.

Right ear lesion score	1st visit		2nd visit	
	Fatteners	Sows/boars	Fatteners	Sows/boars
0	74	52	72	47
1	42	34	50	43
2	9	10	4	4
3	1	0	0	3
4	0	0	0	0
Left ear lesion score	**1st visit**		**2nd visit**	
	Fatteners	Sows/boars	Fatteners	Sows/boars
0	76	49	80	50
1	35	42	35	41
2	15	3	10	6
3	0	2	1	0
4	0	0	0	0

2.1.3.7 Tear stains

The tear stains in the pigs eyes were recorded separately for each eye. Only 49 (22%) of the pigs in the 1st visit and 34 (15%) pigs in the 2nd visit did not have any tears stains in the right eye. Tear stain scoring for the left eye found 52 (23%) pigs in the 1st visit and 29 (13%) pigs not having tear stains. There was no significant effect for the visit season nor the age category of the pigs analysed for both eyes separately. Pigs had higher tear staining score in the left eye was highly likely to have higher tear staining score in the right eye ($P < 0.001$).

Table 2.13 – Number of pigs (fatteners and sows/boars) in each visit with eye stain score

Right eye tear stain score	1st visit		2nd visit	
	Fatteners	Sows/boars	Fatteners	Sows/boars
0	34	18	17	12
1	30	16	28	16
2	23	25	33	27
3	39	37	48	42
Left eye tear stain score	1st visit		2nd visit	
	Fatteners	Sows/boars	Fatteners	Sows/boars
0	34	15	18	16
1	40	15	25	26
2	20	30	40	19
3	32	36	43	36

2.1.3.8 Snout shape and nasal discharge

No snout defects were found in any animal in any farms during both visits. There were no bloody or other coloured discharges in any pig in any farms.

2.1.3.9 Soil shear strength

The difference in soil shear strength was taken as the delta value (shear strength of the no pig area – shear strength of the area of the paddock) and analysed for three separate areas in the paddock (low impact area, foraging area and defecation area). The analysis indicated a highly significant reduction ($P < 0.001$) of the delta value in the foraging area during the 2nd visit compared to the 1st visit. The weakening of the soil strength was present regardless of whether fatteners or sows/boars were present in the paddock (table 2.14). There were no other seasonal or age differences.

Table 2.14 – Comparison of emmeans for soil shear strength (Δvalue) for visit season, with Standard Error (SE) and P-Values

Visit	Fatteners				Sows/boars			
	emmean (shear strength(kPa))	SE	Estimate	P value	emmean (shear strength(kPa))	SE	Estimate	P value
1st visit	-11.05	9.40	43.5	<0.001	2.24	7.86	43.5	<0.001
2nd visit	-54.51	7.86			-41.21	8.46		

2.1.3.10 Plant species diversity

The results indicated that the delta value for the foraging area was significantly different ($P < 0.05$) during the two visits. During the 2nd visit, delta median value of the plant species decreased (-2.4), while the 1st visit had higher number of plant species (-1.3) in the foraging area, indicating that a lower number of plants were present in the foraging area during the 2nd visit, compared to the 1st visit. The comparisons between the number of plant species in the low impact area and defection area revealed no significant differences between seasons. The age category also did not reveal any significant results for all areas within a paddock.

Table 2.15 – The median values of plant species (Δvalue) in two visits and age categories with the significance

ΔArea	Median – visit		P value	Median - Age category			P value
	1st visit	2nd visit		Fatteners	Sows/boars	Mixed	
ΔForaging area	-1.0	-2.3	0.03609	-1.7	-1.0	-1.3	N.S.
ΔLow impact area	0	0	N.S.	0	0	-0.15	N.S.
ΔDefecation area	-1.0	-1.0	N.S.	-1.3	-1.0	-1.15	N.S.

N.S. – Not significant

2.1.4 Discussion

This study provides insights into the welfare of the animals and environmental conditions on outdoor pig farms in Ireland, focusing on the effects of seasonality and age. This is the first cross sectional study on the welfare of animals on outdoor pig farms in Ireland to our understanding. The main animal welfare benefit from outdoor pig production is that pigs can express natural, highly motivated behaviours (Delsart et al., 2020). While animal behaviour was not recorded in the current study the welfare indicators reflected few pig welfare problems in general and only minor seasonal variations and effects of age. There were also some minor seasonal effects on the environmental measurements such as soil and vegetation. However, the findings also raise concerns about some management practices, notably in feeding and management of ecto-parasites in pigs.

2.1.4.1 Animal measurements

2.1.4.1.1 Body condition score

In otherwise healthy pigs, the BCS depends mainly on the availability of the feed. The pigs assessed in our study were in good body condition (score 3 and 4). However, during the 1st visit, the BCS of both fatteners and sows/boars was lower, although not significantly so, compared to at the 2nd visit. Since the 1st visit was conducted in the winter months (February, March) and early spring (April, May), the availability of supplemental forage material was low, and the lower temperatures also might affect fat deposits in the pigs, which could lead to lower BCS. In relation to the age categories, the fatteners in both visits had lower BCS compared to the sows/boars, and during the 1st visit for fatteners, the BCS was the lowest (2.71). Similar to the current study, Leeb et al. (2019) observed that thin sows were rare in organic pig farms in Europe and Scott et al. (2023) found low BCS in only 0.1% of the sows in 81 Dutch and English pig farms. While growing pigs take time to develop their fat deposits, these findings suggest feeding management practices of pigs destined for slaughter might be sub-optimal on the farms and that there may be inadequacies in supplemental feeding of all pigs during the winter months.

2.1.4.1.2 Lameness

Only a few pigs showed abnormal strides (1st visit – 6%, 2nd visit – 1.3%) and there was a complete absence of clinical lameness. The highest lameness score was 1 which is for abnormal strides, in all assessed farms. This is in line with previous studies, which found that lameness in pigs with outdoor access is lower compared to pigs raised in conventional systems (Kilbride et al., 2009; Knage-Rasmussen et al., 2014; Temple et al., 2012). In the present study, the pigs assessed during the 1nd visit had more lameness compared to the pigs during the 2nd visit. Lameness occurs due to several reasons in the pigs. Infectious arthritis, non – infectious degeneration of the cartilage and the bone of the joint and traumatic damage to the limb or foot are the most prevalent (Kilbride et al., 2009). Knage-Rasmussen et al., (2014), in a study undertaken on organic sow herds, found higher prevalence of lameness during the summer/autumn visit which is the opposite to the results of our study. However, their research was conducted in Denmark, which has a slightly different climate to Ireland where it is wetter during winter/spring and the ground tends to be less covered with vegetation potentially increasing the risk of slipping, falling. Sow/boars had poorer locomotory scores compared to the fatteners during both visits which likely reflects an age related deterioration in walking ability of pigs (Wang et al., 2018).

2.1.4.1.3 Presence of external parasites (*Haematopinus suis*)

The prevalence of hog louse (*Haematopinus suis)* was high in some farms. During the 1st visit, the highest presence of hog louse was reported (30%), which was in the winter/spring period when the temperature is lower. A survey done by Wooten-Saadi et al. (1987) reported that the infestation of lice was higher during cooler months of the year in Indiana, US. Another study undertaken in Corsica, by Foata et al. (2006), revealed high numbers of lice in wild boars during the spring months. Results from our study agrees with these findings. In the temperate regions of the world, the populations of lice are dynamic and exhibit pronounced seasonal fluctuations (Taylor et al., 2016). In our case, winter/spring months showed the highest prevalence of lice and the relatively dry and sunny conditions during the summer months may hinder the growth and the spread of lice in pigs. Sows/boars had higher prevalence of lice compared to fattener pigs. This might be due to the fact that the sows/boars were reared separately from the fatteners in most farms and the prolonged infestation might have caused the older pigs which were bigger in body size than the fatteners with more attachment opportunities for lice.

2.1.4.1.4 Skin lesions

Skin lesions are a sign of negative welfare among pigs and lesions can occur due to aggression between animals and injuries caused by trauma associated with obstacles in the environment or falls on hard ground. In our study, the number of fresh lesions was higher in sows/boars compared to the fatteners. In most instances, the surveyed farms kept sows of different ages (e.g. – 2 years old and 7 years old) in the same paddock and, although not quantified, aggression and bullying between sows was observed in the majority of cases, especially during feeding which tended to be restricted (Menant et al., 2023).

The number of old lesions was higher in the 2nd visit than in the 1st visit. This was also the case for the sum of all lesions (fresh and old) on the pig's bodies. Guy et al. (2002) found that the final injury score on pig bodies from several management systems was highest during the months of April – July. Another study done on male pigs, by Prunier et al. (2013), showed that the lesion counts were higher in the spring months compared to the autumn months. These results are similar to the results from our study, especially for the sum of all lesions. The differences in the temperature and other environmental conditions might result in the fluctuations of the skin lesions present in the pigs due to the growth of plants and due to temperature related stress. The sows/boars had a higher number of lesions (old/sum of all) compared to fatteners in both visits. This could be due to sows/boars living a longer life compared to fatteners, thus accumulating more lesions over a number of years.

2.1.4.1.5 Tail loss and tail lesions

Tail biting is a common problem in intensive farming systems in the world; however, tail biting is rare in outdoor production systems (Leeb et al., 2019). Our study confirms these findings, as the majority of the pigs had intact tails with no lesions (1st visit – 97%, 2nd visit – 93%), and pigs with tail loss were present in a small number of particular farms only. Lesions present in the tail could be due to some other cause such as an injury from an environmental source. During our visits we did not observe tail biting behaviour among the pigs.

There was a trend for the observed tail lesion scores to be higher during the 2nd visit compared to the 1st visit. This may be due to the higher temperatures experienced by the pigs during the summer months (D'Eath et al., 2014), and also there was a group of pigs with no tails in one farm that might be indicative of a tail-biting outbreak, however this was not investigated further. In general, pigs assessed during the farm visits had a large area in which to perform their natural behaviours and were supplied with manipulable materials which likely explains why the majority of pigs had intact tails with no lesions.

2.1.4.1.6 Ear lesions

The number of pigs with ear lesions was comparatively high since 43% of pigs during the 1st visit and 47% during the 2nd visit had some form of ear lesion. Ear biting in outdoor pigs is not common and studies report that behaviours relating to ear manipulations are rare (Høøk Presto et al., 2008). We did not observe ear biting behaviour among pigs during the assessments hence the aforementioned ear biting could be due to external injuries (e.g. – physical injuries from the environment). However, it would be worthwhile to investigate this further to see whether there is any ear biting occurring in the farms.

2.1.4.1.7 Tear staining

Tear staining was high among pigs assessed during the farm visits, although there were no significant relationships between visits or with age. Tear staining is an indicator of underlying physiological and environmental stress in pigs (Telkänranta et al., 2016; Larsen et al., 2019). Tear staining can also indicate social isolation and aggression among pigs (Marchant - Forde, 2014; DeBoer et al., 2015). Holinger et al. (2018) pointed out that the tear staining increased with the age in organic pig farms and an average tear staining score of 2.5 out of 5, which could be similar to what we observed. Since pigs reared outdoors experience changing environmental conditions, the tear staining could be a result of the regular changes in the weather conditions as a large number of pigs had tear staining on at least one eye. However, aggression cannot be ruled out as a reason for high tear staining recorded during the visits, and it most likely due to a mixture of both environmental and physiological factors. It is also possible that this welfare indicator is not valid for use in outdoor settings.

2.1.4.2 Environmental measurements

2.1.4.2.1 Soil shear strength

Soil compaction is an issue in outdoor pig farming, due to the pigs' rooting and foraging behaviours (Quintern & Sundrum, 2006). During our study, there was a significant difference of ΔShear value in the foraging area in the paddock such that the soil strength was weaker at the 2nd visit. This could be due to foraging behaviour of pigs increasing during the summer/autumn months due to the availability of grasses and plants. This could increase rooting behaviour and thus create a more poached and weakened soil. However, compaction does not solely depend on rooting behaviour and other factors such as soil type and stocking density play a considerable role. In our case also, different soil types in different paddock might had an effect in shear values.

2.1.4.2.2 Plant species richness

The number of different plant species in the foraging area decreased between the 1st and 2nd visit. This likely reflects the fact that there were more plants during the summer/autumn months; however, the decrease implies that the pigs were able to remove the plants with their foraging. Pigs rapidly remove herbage cover from paddocks however, pigs show selectivity while foraging and some plants are avoided, probably due to toxicity (Edwards, 2003; Nota et al., 2023). During the visits, we observed a similar pattern as some plants were not eaten by pigs (e.g. – broad leaved dock (*Rumex obtusifolius*)) and some plants were highly preferred.

2.1.5 Conclusions

The results highlight minor seasonal differences in animal welfare and environmental measures. Seasonal differences were observed in the animal-based parameters where at the 1st visit pigs had higher cases of abnormal gait (lameness) and hog lice while the 2nd visit showed higher number of skin lesions and higher tail lesion score. Sows/boars displayed higher instances of abnormal gait, parasite presence, and skin lesions than fatteners, likely reflecting age-related susceptibility to these issues. Fatteners showed lower body condition scores compared to sows and boars, however the difference was not large. The environmental measurements displayed weaker soil structure in the 2nd visit than in the 1st visit in the foraging area in the paddock. The number of different plants in the 1st visit was higher than in 2nd visit, suggesting higher frequency of foraging or trampled in heavy poaching of the plants by pigs during summer/autumn months. This study provides a cross sectional overview of the welfare indicators of outdoor reared pigs and majority of the animals had favourable welfare indicators, with only a small proportion showing negative indicators. While this study provides valuable insights, it could benefit from incorporating additional welfare indicators to better reflect thermal comfort, absence of prolonged thirst, and freedom from disease. Metrics such as the prevalence of sunburn, panting scores, and the availability of drinking water could enhance the assessment. Existing measurements, like tear stain scores, should also be re-evaluated, as they may reflect environmental factors rather than animal welfare. The environmental measurements, though informative, were somewhat superficial. A more comprehensive approach could include soil indicators such as soil pH, organic content, and biodiversity (e.g., soil nematode diversity), as well as water quality assessments. Additionally, biodiversity metrics, including plant species identification and wildlife monitoring, would provide a more holistic understanding of the farm environment. Longitudinal assessments could further strengthen the study by elucidating the relationships among these parameters over time. This approach would not only deepen our understanding of current findings but also highlight the potential positive impacts on animal welfare. Such insights could inform strategies to improve welfare conditions for animals reared in other systems.

Chapter 2b

2.2 A 'One Welfare' analysis of animal, environmental and human welfare of Irish outdoor pig farms

2.2.1 Abstract

The 'One Welfare' concept emphasizes the interconnectedness between animal, environmental, and human welfare, yet limited studies have explored these interrelations in farmed animal systems. This study investigates the interconnections between pig welfare, environmental parameters, and farmer well-being in outdoor pig farms in Ireland. Data were collected from 223 pigs across 17 farms during visits conducted between July and October 2023. Animal welfare indicators included body condition score (BCS), lameness, skin lesions, ecto - parasite presence, and tear stain scores. Environmental measures included soil shear strength and plant diversity, in delta values calculated relative to baseline measurements outside paddocks. Farmer well-being was assessed using a quality of life (QoL) questionnaire developed by the World Health Organisation (WHO). Principal component analysis (PCA) revealed three distinct clusters. Cluster 1, characterized by low animal welfare (high lameness, lesion, and ecto-parasite scores), primarily comprised paddocks with sows and boars. Cluster 2 exhibited high animal welfare but low farmer well-being scores, often associated with organic or GMO-free farms. Cluster 3 represented paddocks with the highest overall balance of animal welfare and farmer well-being, typically housing fattener or grower pigs. Significant differences ($P < 0.05$) were observed between clusters for several animal welfare measures, soil shear strength in foraging areas, and plant diversity in defecation areas. Farmer well-being scores varied significantly ($P < 0.001$) across clusters, with Cluster 2 scoring lowest. These findings highlight the preliminary exploration of trade-offs between animal welfare and farmer well-being in outdoor pig farming systems while using a 'One Welfare' approach to look at the relationships between each area. Further studies are needed to explore causal relationships and refine strategies for optimizing welfare across all three dimensions.

Keywords – Outdoor, pigs, PCA, One welfare, holistic, quality of life

2.2.2 Introduction

The perspective of the welfare of farmed animals is evolving and society is increasingly concerned about it. Historically, the interconnectedness between animals, the environment, and farmers has not been a primary focus of welfare studies. The 'One Welfare' concept addresses the gap by emphasizing the interconnectedness between the animal, the environment and human welfare and argues that improvements or impairments in each area can influence the others (Pinillos et al., 2016). This framework is based on the integration of metrics of environmental sustainability with animal welfare and human well-being to ensure that no one sustainability 'pillar' is optimised at the expense of the other.

Outdoor pig farming is perceived as a 'welfare friendly' system as it allows the pig to perform natural behaviours while providing access outdoors. Many studies compared the welfare of pigs reared in outdoor farming systems with various welfare indicators and most studies report generally positive outcomes for pigs while outlining mortality and parasites as persistent health and welfare challenges (Guy et al., 2002; Leeb et al., 2019; Nakamura et al., 2011; Yonezawa et al., 2012). Several studies reveal a negative impact of outdoor pig production on the environment such as soil degradation and biodiversity loss (Halberg et al., 2010; Horta et al., 2022). Farmer well - being in outdoor pig settings is rarely studied, but research findings so far, suggest that lack of support and high feed prices affect the well – being of the farmer in alternative production systems (Brajon et al., 2024).

Spigarelli et al. (2021) explored the welfare of cows and the satisfaction of the farmers who reared them in the mountain regions of Italy. They observed that the welfare of the animals was good where farmers had positive relationships with the agricultural and non - agricultural community and were satisfied with the land organization of their land. Given that many Irish outdoor farms operate on a small scale (Menant et al., 2023) exploring each component of 'One Welfare' will provide an understanding of the relationships between animal, environment and human factors. This preliminary analysis aims to explore these relationships and contribute to the growing body of knowledge on integrated welfare frameworks.

2.2.3 Materials and methods

Farms were visited twice where data on pig welfare and environmental parameters are reported (Chapter 2.1). This study consists of the data taken during the 2nd visit to the farms which occurred between July and October 2023. Seventeen farms were visited during this period and animal welfare, environmental and farmer related measurements were taken using observational scoring, sampling and farmer surveys. Data were obtained at the paddock level (29 paddocks).

2.2.3.1 Animal welfare measurements

Two hundred and twenty three animals were observed and body condition score (BCS), lameness, tail lesions, ear lesion (mean score for both ears) and tail lesion scores were measured using scoring systems (Chapter 2.1). Skin lesions were observed and counted across the pig body. Presence of external – parasites (hog louse) were recorded. Tear stain (mean score for both eyes) scores were observed and recorded. All scores and counts were averaged at the paddock level.

2.2.3.2 Environmental measurements

Each paddock was divided into areas of usage by the pigs (i.e. foraging and defecation). Soil shear strength was measured in each area in the paddock (three measurement per each area and averaged) and outside the paddock as a baseline measurement. The shear strength value of each area was subtracted from the shear value of the outside of the paddock and the delta value was obtained. The number of different species of plants were also counted in the two usage areas of the paddock (foraging and defecation) and outside of the paddock. The number of plants in each area was subtracted from the number of plants outside of the paddock and the delta value (positive or negative) was obtained.

2.2.3.3 Quality of life of the farmers

Farmers (on farm basis) (n=17) completed a quality of life (QoL) questionnaire developed by the World Health Organization and questions were scored accordingly (WHO, 2012) (See appendix). Four sub section scores were produced based on the scores: physical, psychological, social relations and environment. Scores were given at 0 -100 scale. Higher QoL scores indicated high well-being score while lower scores indicated low well-being. Overall QoL score was produced at 0 – 5 scale after totalling all of the sub sections.

2.2.3.4 Principal component analysis (PCA)

A PCA was conducted using FActMineR and missMDA packages on Rstudio software (R version 4.3.1, R core team, 2022). All the data was scaled to 0 to 1 scale before analysis and PCA was carried out. A biplot was obtained and clusters were created to visualise the analysis. Means of each variable were calculated for each cluster and an ANOVA was performed to compare clusters. A Tukey's test was performed as a *post hoc* test.

2.2.4 Results

The bi-plots captured variations of 13.7% from dimension 1 and 34.5% from dimension 2. The results revealed three distinct clusters. Each cluster was named according to the characteristics shown by each of the mean scores in the cluster (Table 2.16).

- Cluster 1 – Low animal welfare cluster
- Cluster 2 – Low quality of life cluster
- Cluster 3 – Average cluster

Cluster 1 represented paddocks where sows were kept (4 paddocks). This cluster had the highest average scores for animal welfare measurements (lameness, presence of ecto – parasites, skin lesions, ear lesion score, tail lesion score, tear stain score), and hence had the lowest animal welfare. However, it also had the highest average number of plants in both areas in the paddock. The average QoL scores were higher (>80%) on the farms with paddocks in this cluster. Cluster 2 represented 5 paddocks in three farms. This cluster had the lowest scores for animal welfare measurements apart from the presence of ecto – parasites hence, the highest level of animal welfare. However, this cluster had the lowest QoL for farmers, which was averaged around 50%. In terms of environmental measures, this cluster had the lowest soil compaction out of the three clusters and the farms in this cluster were not conventional outdoor farms (either organic or providing genetically modified organism free feed). Cluster 3 contained the highest number of paddocks (n = 20 out of 29 paddocks) and it had lower average scores in terms of animal welfare measurements. The QoL of the farmers was also higher (average scores >80%) in every sub section. The ANOVA results revealed differences ($P < 0.05$) between the three clusters in lameness (F value – 7.471, df – 2), skin lesion count (F value – 6.661, df - 2), mean ear lesion score (F value – 6.176, df - 2) and the mean tear stain scores (F value – 3.674, df – 2) in terms of animal welfare measurements. The soil shear strength was different in the foraging area (F value – 3.832, df – 2) within the three clusters. The plant species diversity was significantly different in the defecation area (F value – 3.386, df – 2) and there was a trend in the foraging area. All of the QoL measurements were highly significant ($P < 0.001$) across all the clusters.

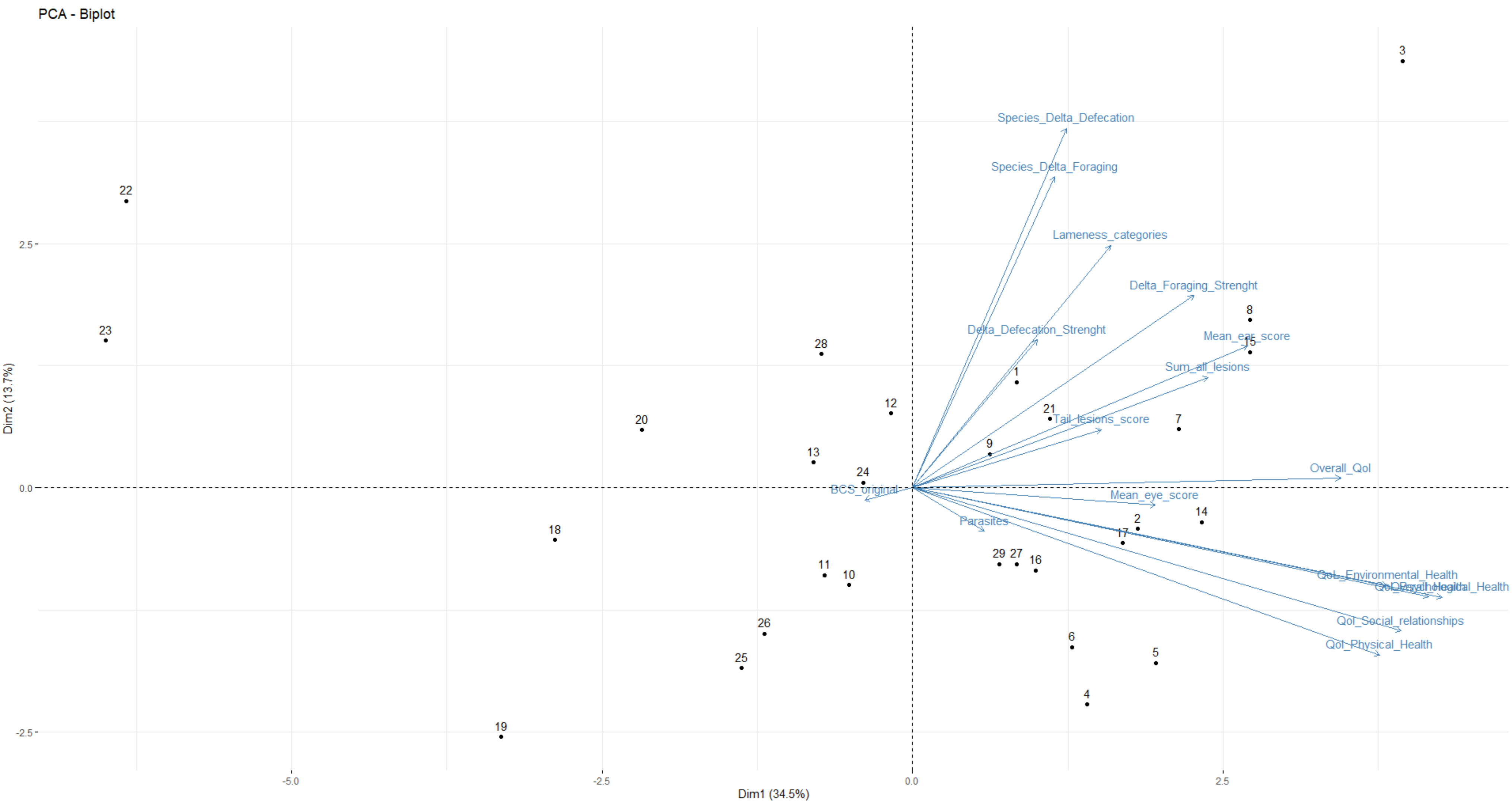

Figure 2.4 – Biplot of the directions of the measurements and the position of the paddocks (in numbers) in the grid

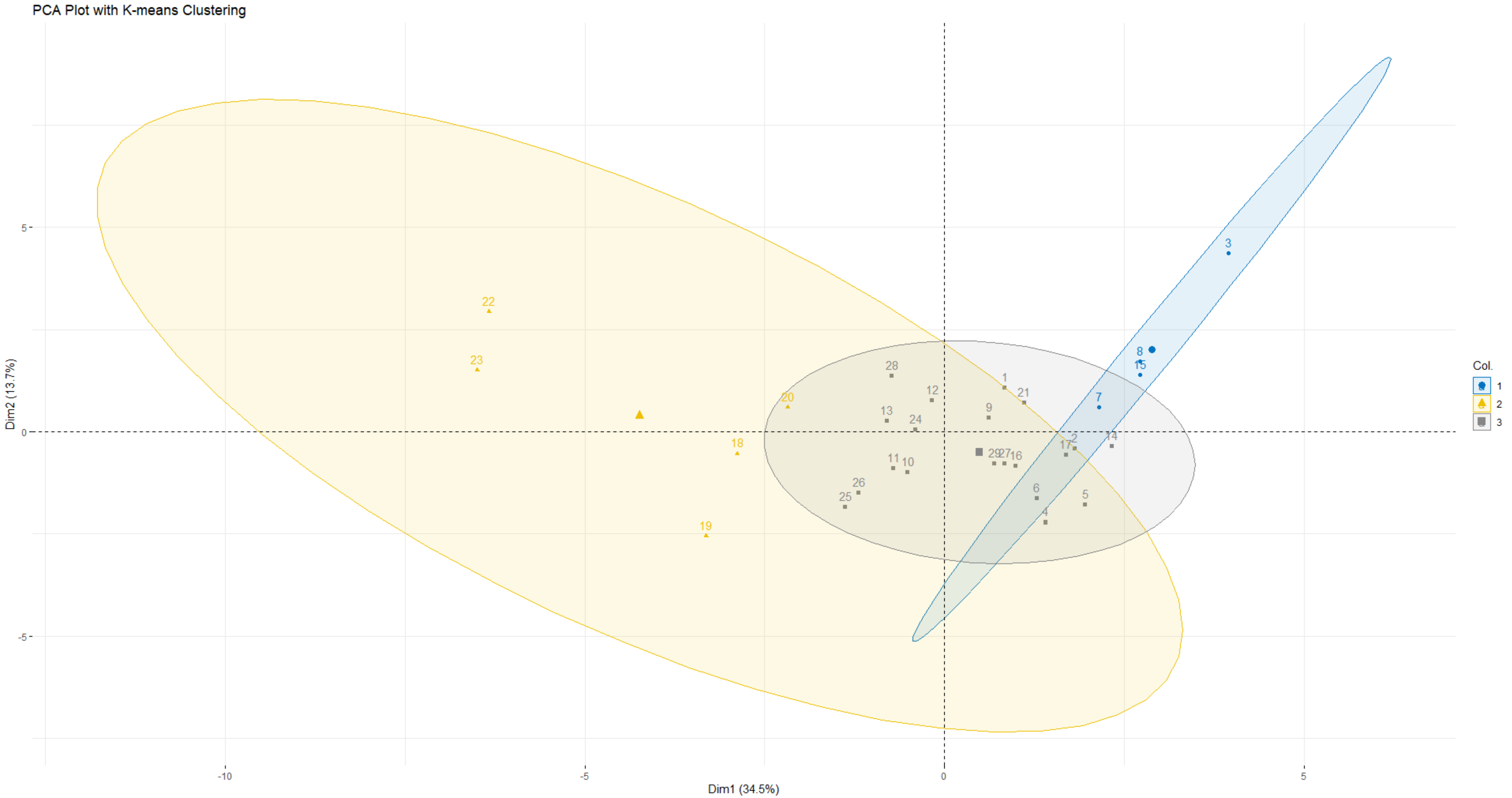

Figure 2.5 – Cluster positions in the grid in different colours. Each number represents one paddock (cluster 1 – blue; cluster 2 – yellow; cluster 3 – grey)

Table 2.16 – mean values and standard error (SE) of the scores and measurements in each cluster with the P – value of the ANOVA.

	Mean ± SE			
	Cluster 1	Cluster 2	Cluster 3	P- value
Animal welfare measurements				
Body condition score	3.2 ± 0.15	3.16 ± 0.51	3.3 ± 0.12	NS
Lameness	0.1 ± 0.07	0	0	<0.01
Ecto – parasites	0.2 ± 0.16	0.18 ± 0.18	0.13 ± 0.06	NS
Skin lesions	3 ± 0.7	0.3 ± 0.13	1.1 ± 0.26	<0.01
Tail lesion score	0.3 ± 0.23	0	0.1 ± 0.04	NS
Mean ear lesion score	0.9 ± 0.14	0.3 ± 0.14	0.5 ± 0.05	<0.01
Mean tear stain score	2.4 ± 0.25	1.3 ± 0.33	1.7 ± 0.13	0.039
Environment measurements				
(i) Soil shear strength (Δvalue)				
Foraging area	-17.7 ± 13.3	-82 ± 15	-46.3 ± 8.2	0.03
Defecation area	29.6 ± 32.9	-37.2 ± 28	-11.6 ± 14	NS
(ii)Plant species diversity (Δvalue)				
Foraging area	-0.3 ± 0.8	-2.86 ± 0.8	-2.3 ± 0.3	0.05
Defecation area	1.2 ± 0.9	-1.6 ± 1.2	-1.1 ± 0.3	0.04
Quality of life				
Physical health	87.3 ± 4.4	45.8 ± 14.2	90.1 ± 1.4	<0.0001
Psychological health	94 ± 2.5	52.6 ± 8	83.8 ± 1.9	<0.0001
Social relationships	95.8 ± 4.3	36.6 ± 16.7	83 ± 4	<0.001
Environmental health	81.3 ± 3.4	40 ± 7.4	81 ± 2.7	<0.0001
Overall health	4.6 ± 0.25	2.6 ± 0.24	4.6 ± 0.1	<0.0001
Overall Quality of life	5	4	4.5 ± 0.1	<0.01

NS - Not significant

2.2.5 Discussion

The three clusters had specific differences in terms of animal welfare and QoL of the farmers. The environmental parameters were less specific, probably because there were only two measurements, namely soil shear strength and plant species diversity. Cluster 1 had low animal welfare and all the paddocks contained sows and boars. The poorer welfare status might be due to the older age of these animals, as discussed in the previous chapter, where sows/boars had higher welfare scores compared to fattener pigs for lameness, lesions and ecto - parasites. Dippel et al. (2018) found that 18.8% of sows in 101 organic farms across Europe were lean compared to fattener pigs. Furthermore, they found more lesions and lameness in sows. Vaarst et al. (2000) reported that lameness, injuries and sunburn were the most common ailments in the outdoor breeding herd in Denmark. Day et al. (2003) found that ecto – parasites were the main health concern in outdoor breeders in the UK. We found similar results for animals in cluster 1.

Cluster 2 had low QoL scores compared to other two clusters. This cluster consisted of five paddocks representing three farms. Two of the farms were certified organic and the other farm was providing GMO free feed to the pigs. Brajon et al. (2024) interviewed French outdoor pig farmers and found the lack of support as one of the main issues. The cost of feed was also an issue for the farmers. In the case of our study, the low QoL scores might reflect similar constraints faced by Irish outdoor pig farmers.

Cluster 3 had the highest number of paddocks (20 paddocks) which were scored in low welfare scores, indicating higher levels of welfare, relatively low compaction and high farmer QoL scores seemingly representing relatively good conditions in all levels. Nevertheless, this cluster also included farms with paddocks of fatteners and grower pigs that were also represented by paddocks of sows and boars in cluster 1. This seemingly reflects disparate treatment of the breeding and fattening stock on the same farms with better attention paid to the latter as they are the economic output from the farm.

2.2.6 Conclusions

This preliminary analysis explored the interconnections between pig welfare, environmental conditions, and farmer well-being within the framework of 'One Welfare'. The findings indicated that paddocks housing sows and boars exhibited the poorest animal welfare metrics, whereas some farms with organic or GMO-free certification achieved the highest animal welfare standards, but had the lowest QoL for the farmers. Most paddocks, however, maintained a balance with optimal levels of both animal welfare and farmer well-being. Of potential cause for concern is the seemingly different standard of husbandry offered to sows and boars compared to fattening pigs (e.g. – provide less feed) within the minority of farms that kept breeding stock. This could reflect labour challenges because of looking after larger number of animals, knowledge gaps or low priority towards sows and boars as fattener pigs are the final product of the farm. Clearly a larger number of farms to include in the analysis would have strengthened the results. However, this initial investigation lays the groundwork for a more sophisticated analysis, offering the potential to uncover causal relationships between the interconnected components of the 'One Welfare' framework.

Chapter 3

Effects of season, age and parasite management practices on gastro – intestinal parasites of outdoor pig farms in Ireland

3.0 Effects of season, age and parasite management practices on gastro – intestinal parasites of outdoor pig farms in Ireland

Accepted by Irish veterinary journal

3.1 Abstract

Outdoor pig farming gained popularity in recent years as it offers pigs considerable behavioural freedom and better consumer acceptance. However, gastro – intestinal (GI) parasites pose a significant health and welfare challenge for pigs reared outdoors. Sixty five pig faecal samples (paddock level samples mixed from at least 2 – 4 animals per paddock) were collected from 20 outdoor pig farms with 65 paddocks over two visits (1st visit – February/May 2023, n = 37, 2nd visit – July/October 2023, n = 28). Samples were collected and mixed thoroughly to achieve a paddock level sample. Data related to pig type (fatteners, sows and boars), anthelmintic usage (Yes/No) and paddock rotation (Yes/No) were also collected and categorized at paddock level. Samples were analysed using the McMaster floatation method, faecal egg count (FEC) was calculated, and GI parasites were identified by morphology. Generalized linear mixed models were used to analyse the effect of season, age, anthelmintic usage and paddock rotation on FEC. Four parasite taxa were identified (*Eimeria* spp., strongyles, *Ascaris suum* and *Trichuris suis*). Infection rates were >80% for *Eimeria* spp. and strongyles, 31% for *A. suum* and 9% for *T. suis* for both visits. *Eimeria* spp. FEC was higher during the 2nd visit ($P < 0.001$) and strongyles FEC was higher in the 1st visit ($P < 0.05$). Fattener pigs had higher FEC for *Eimeria* spp. ($P < 0.01$) and sows/boars had higher strongyle counts ($P < 0.05$). Strongyle count was lower with anthelmintic use ($P < 0.05$) and *Eimeria* spp. count was lower ($P = 0.05$) with paddock rotation when anthelmintics were used. The seasonal variation in the egg count could be due the differences in the weather. This study provides the first comprehensive picture of GI parasites in outdoor pig farms in Ireland in terms of the types/species and their prevalence which is moderately high. The findings also suggest that there are some deficiencies in the management practices used to control GI parasites on these farms.

Keywords: Outdoors, Gastro – intestinal, pigs, parasite, season, worms

3.2 Introduction

Infection with gastro–intestinal (GI) parasites is a cause of ongoing and increasing concern in livestock production because of detrimental economic and animal welfare effects, which negatively affects sustainability of the industry (Charlier et al., 2020; Crawley et al., 2016; Donald, 1994). Detrimental implications for animal health are associated with morbidity, reduced feed conversion efficiency, and growth, as well as treatment costs (Maqbool et al., 2017; Perry & Randolph, 1999). Effective control of GI parasites requires a combined use of anti-parasitic drugs and management practices such as rotational grazing (Pettersson et al., 2021). Increasingly there are also concerns for resistance to treatment (Walker, 1997). GI parasites, particularly helminths, affect domestic pigs in all production systems around the world (Roepstorff et al., 2011). In pigs, infections impair intestinal absorption, prolong the fattening period, delay or hamper immunity after vaccination, reduce meat quality, and in the case of young pigs, may cause them to die, due to diarrhoea and dehydration (Knecht et al., 2011; Kochanowski et al., 2017). In spite of the potential clinical implications, parasitic infections in pigs seldom cause clinical symptoms, especially in the case of helminths, and diagnosis is generally based on laboratory examinations (Roepstorff et al., 2011; Kochanowski et al., 2017). The subclinical nature of helminth parasitic infection means that they receive less attention compared to other parasites in other livestock species. An additional risk of GI infections in pigs is the potential for zoonoses associated with helminth species such as *Ascaris* and *Trichuris* (Nejsum et al., 2012).

While the majority of pigs in developed countries are farmed intensively, the increasing interest in welfare-friendly meat means that there is growth in the outdoor pig production sector (Thorslund et al., 2017). Outdoor pig farming allows pigs to express a wider range of behaviours in a more natural environment (Delsart et al., 2020). However, outdoor access increases the risk of both endo- and ecto-parasitic infection, due to favourable conditions for the development and survival of various stages of parasites in the outdoor environment (Salajpal et al., 2013). Transmission occurs through ingestion of infective eggs, oocytes and larvae. Common parasites in outdoor pigs include protozoa (e.g. *Eimeria* spp., *Isospora suis*, *Balantidium coli* etc.) and helminths (e.g. Strongyles, *Ascaris suum*, *Trichuris suis*, *Metastrongylus* spp.) (Taylor et al., 2016). Several studies reported the prevalence of a range of parasite species in outdoor reared pigs in Europe. Delsart et al. (2022) assessed 70 alternative farms in France and reported 79% of the farms having coccidia and 47%, 16% and 36% of farms having *Oesophagostomum* spp., *Ascaris suum* and *Trichuris suis* respectively. There are differences in the prevalence of parasites in different age groups of pigs (Eijck and Borgsteede, 2005; Băieş et al., 2022). (Carstensen et al., 2002) assessed 9 organic pig herds in Denmark and found *Ascaris suum, Oesophagostomum* spp. and *Trichuris suis* among weaners, fatteners and sows with varying levels of prevalence. Băieş et al. (2022) examined 960 free-range pigs in Romania and observed that the pigs had *Eimeria* spp., *Balantidium coli*, *Ascaris suum*, *Oesophagostomum* spp., *S. ransomi* and *Cryptosporidium* spp. Furthermore, the number of parasites, and hence the potential infective pool, in the paddock fluctuates with the seasons, indicating parasite's sensitivity to temperature changes (Miao et al., 2004; Băieş et al., 2022b).

There is no established outdoor pig production industry on the Island of Ireland with farms being more 'backyard' in nature. Menant et al. (2023) reported an average of 7 sows/gilts, one boar, 18 grower pigs and 17 piglets in these small scale production units at any one time, which were generally managed by two people. The main breeds were Duroc, Oxford sandy and black, Tamworth, and Gloucester old spot pigs. Pigs were reared in agro-forestry systems, on pasture or in a mixture of both. Considering the small-scale nature of the industry, it is poorly characterised and literature on GI parasites is scarce. In order to address this knowledge gap, the objectives of this study were to:

1. Identify and evaluate the prevalence of GI parasites in outdoor reared pigs on selected farms;
2. Determine the effect, if any, of season, sex and age on the parasite faecal egg counts
3. Assess the effect of anthelmintic treatment and paddock rotation on the parasite egg burden

3.3 Materials and methods

3.3.1 Farms and animals

Twenty farmers were selected from 57 respondents to the survey described by Menant et al. (2023), and volunteered to participate in the current study. Farms were located in 12 out of 32 counties across the island of Ireland (1 each in Antrim, Clare, Down, Galway, Tipperary, Sligo, Louth and Wexford, and 3 in Cork, Laois, Waterford and Wicklow). Each farm was visited twice: once between December, February and May 2023 (winter/spring) and once between July and October 2023 (summer/autumn). The first visit encompassed 19 farms, with 17 farms visited during the second phase (Table 3.1). All of the assessed farms had an electrified fenced outdoor area where the pigs had access to soil. The assessed farms included 6 organic farms (Table 3.1). Information on various parameters, including animal demographics (age, breed) and management practices such as anthelmintic usage (yes/no) and paddock rotation (yes/no) were also collected (Table 3.1). Pigs older than 3 months were selected for inclusion, while lactating sows and piglets under 3 months old were excluded due to practical issues with data collection and the aggressive nature of the lactating sow. Animals were stratified into two age categories: fatteners (comprising growing and finishing pigs under 8 months old) and sows and boars (encompassing sows and boars aged 9 months to 4 years, Table 3.1).

3.3.2 Sample collection

Between 2 - 4 faecal samples were collected in each paddock in which pigs were present. The pigs were observed until defecating freely, the samples were promptly collected after voiding, placed into 100 ml plastic cups, and stored under chilled conditions (0–4 °C). Each sample within a paddock was combined in equal proportions to create a composite paddock-level sample. Only faecal samples with solid nature were collected. In total, 65 paddock level samples were collected over the two visits (Table 3.1), with 37 samples in the first visit and 28 samples during the second visit. These samples were maintained under chilled conditions during transportation and stored in a cold room at 4 °C until the coprological analysis was conducted. All samples were analysed within 21 days after collection.

Table 3.1 Characteristics of the farms visited

Farm no	Breeds	Organic system	Visit		Age		Anthelmintic use		Paddock rotation	
			1st	2nd	Fatteners	Sows/ boars	Yes	No	Yes	No
1	Duroc, GOS, OSB, Tamworth	No	√	√	√	√	√		√	
2	Duroc, OSB	Yes	√	√	√	√		√	√	
3	Duroc, Hampshire, Large Black, OSB	Yes	√	√	√	√		√	√	
4	Berkshire, OSB, Tamworth	Yes	√	√	√	√		√	√	
5	Duroc, OSB	No	√	√	√	√		√	√	
6	British saddleback, Duroc, GOS, Hampshire	No	√	√	√	√		√		√
7	OSB, OSB cross breeds	No	√	√	√	√	√		√	
8	OSB	No	√	√	√	√	√		√	
9	OSB	No	√	√	√	×	√			√
10	Tamworth, Vietnamese pot bellied	Yes	√	√	√	√		√	√	
11	Tamworth	Yes	√	√	√	√		√	√	
12	Duroc, OSB, Tamworth	No	√	√	√	√	√		√	
13	Large Black, Midddle White, Tamworth	No	√	√	√	√	√		√	
14	Duroc, British Saddleback	Yes	√	×	×	√		√		√
15	Kune Kune, Idaho pasture pigs	No	√	×	√	√		√	√	
16	Duroc, GOS, Landrace	No	√	×	√	√		√	√	
17	Mangalista	No	√	√	√	√		√	√	
18	Berkshire, Duroc, Large White	No	√	√	√	×		√	√	
19	Landrace, Large White	No	√	√	√	√	√		√	
20	Duroc, OSB	No	×	√	√	√		√	√	
	Total	6	19	17						

GOS: Gloucester Old Spot, OSB: Oxford Sandy and Black

3.3.3 Coprological analysis

A modified McMaster floatation method described by Taylor et al. (2016) was utilized for the analysis of faecal egg count (FEC), employing NaCl as the floating solution. Initially, 3g of faecal matter from the mixed-level sample was placed into a mortar and homogenized with 42ml of chilled water (0-4 °C). The resulting homogenized sample was then sieved through a 150 µm sieve, and the filtrate was transferred to 15 ml centrifugal tubes, which was subsequently centrifuged at 1500 rpm for 2 min. After centrifugation, the supernatant was removed, and saturated NaCl solution was added. The pellet was then disrupted using a vortex, ensuring thorough mixing. The tubes were inverted 8-10 times, and the mixture was pipetted out from the middle of the tube and transferred to a two-chambered McMaster slide. Subsequently, the grid of the slide was examined using a microscope (Alphaphot – 2 YS2, Nikon Corporation, Tokyo, Japan) at 10x magnification to detect parasite eggs. Different types of parasite eggs or cysts were identified based on their morphology (Taylor et al., 2016), and the number of different eggs in the grid per chamber was counted. The technique had a lower limit of 50 eggs/g per sample. Three replicates (slides) were analysed for each faecal sample. The faecal egg count) is displayed as eggs per gram of faeces (eggs/g) and calculated using the following equation:

$$Faecal\ egg\ count = (egg\ count\ in\ chamber\ 01 + egg\ count\ in\ chamber\ 02) \times 50$$

3.3.4 Statistical analysis

Statistical analysis were performed using Rstudio (R version 4.2.1, R core team, 2022).

3.3.4.1 Prevalence of parasites within visits

Prevalence at the farm level was determined considering the presence or absence of the parasite eggs or oocysts. A farm was considered infected with a specific parasite if at least one egg was detected. The prevalence value for a parasite species was calculated as a percentage of farms infected from the number of all the farms for both visits separately. Fisher’s exact test was used to analyse the prevalence of a parasite between visits.

3.3.4.2 Effect of the season, age and sex on the faecal egg count

A Generalized Linear Mixed Effect Model, utilizing the glmmTMB package (Brooks et al., 2017) was employed to investigate the impact of season and age on the Faecal Egg Count (FEC). To address the zero-inflation observed in the data, a negative binomial distribution with a log link function, along with zero-inflated adjustments, was applied. Fixed effects included season and age while paddock nested within farm was considered as a random effect to account for potential clustering effects. Interactions between fixed effects were considered for analysis Subsequently, a Type III Analysis of Variance (ANOVA) (car package; Fox, 2007) was conducted to validate the model's findings. Estimated marginal means were then derived for further interpretation of the results and pairwise comparisons between the visits and the age groups were conducted.

3.3.4.3 Effect of using anthelmintics and paddock rotation on the faecal egg count

A similar Generalized Linear Mixed Effect Model was used to analyse the effect of using anthelmintics and paddock rotation on FEC. Anthelmintic usage and paddock rotation were included (interaction considered) as fixed effects while paddock nested within farm was used as a random effect.

3.4 Results

3.4.1 Parasite taxa

Four taxa of parasite eggs were identified based on egg morphology (Figure 3.1). They were *Eimeria* spp., strongyles, *Ascaris suum* and *Trichuris suis*. Strongyles were grouped as several species (*Oesophagostomum* spp., *Hyostrongylus rubidus*) have similar morphology and it was not possible to identify the species by morphology.

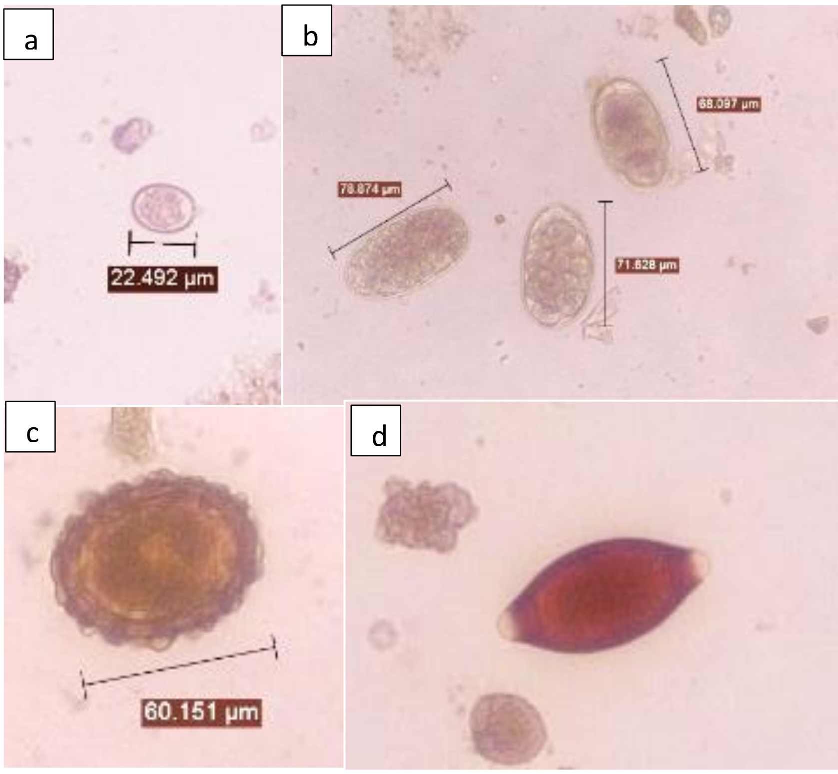

Figure 3.1 – Photographs of *Eimeria* spp. oocyst (a.), strongyle eggs (b.), *Ascaris suum* egg (c.) and *Trichuris suis* egg (d) identified on bright-field microscope (20x magnification)

***3.4.*2 Prevalence of parasites**

Prevalence of *Eimeria* spp. and strongyles were at high levels (>80%) in both visits *and Ascaris suum* prevalence was at around 30%. *T. suis* was found on one farm during the 1st visit and on two farms on the 2nd visit (Table 3.2). There was no significant effect of the visit on the prevalence of each parasite (Table 3.2).

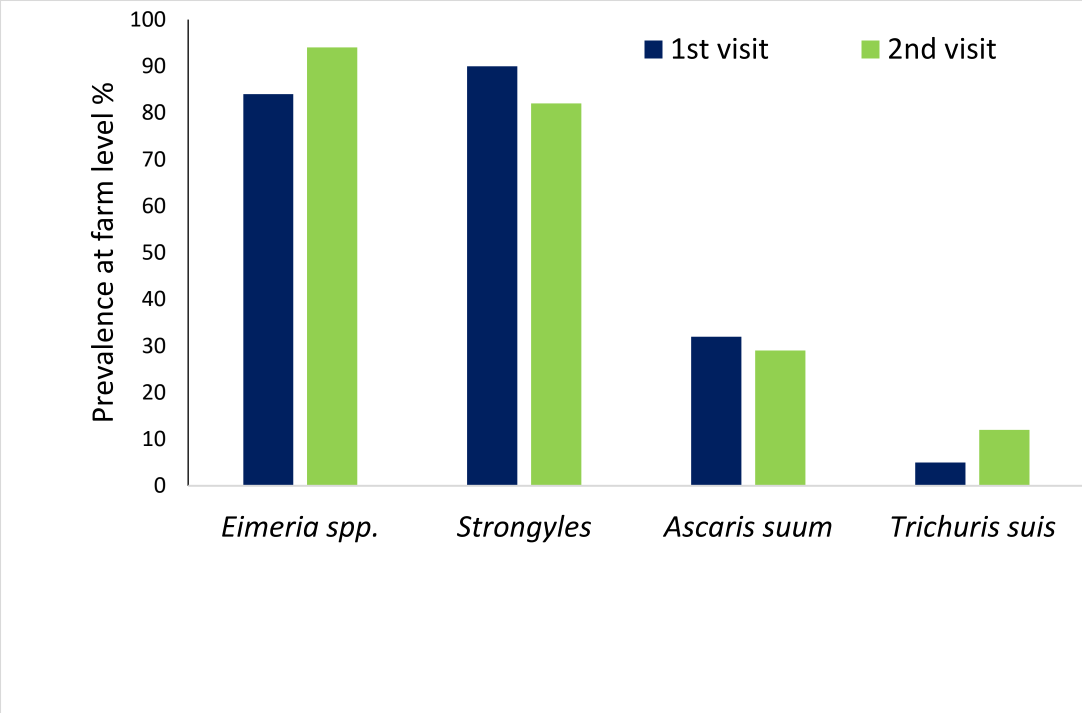

Figure 3.2 – The prevalence of the GI parasites at farm level observed during the 1st (blue) and 2nd visit (green).

Table 3.2 – Number of farms with the presence and absence during two visits and the p values from the Fisher's exact test to determine the significance between farms in two visits

Season	1st visit (19 farms)		2nd visit (17 farms)		P - value
	Present	Absent	Present	Absent	
Eimeria spp.	16	3	16	1	N.S
strongyles	17	2	14	3	N.S.
Ascaris suum	6	13	5	12	N.S.
Trichuris suis	1	18	2	15	N.S.

N.S – Not Significant

3.4.3 Effect of season and age on faecal egg count

There was a significant difference in the FEC for *Eimeria* spp. between visits across all farms (Estimated marginal means ± sd; 1st visit – 476 ± 297 vs 2nd visit – 1527 ± 950 eggs/g; P < 0.001). Furthermore, the *Eimeria* spp. FEC differed (Fatteners – 1175 ± 745 vs Sows and boars – 619 ± 386 eggs/g; P < 0.05) between the two age groups. Strongyle FEC also differed between the two visits (1st visit – 370 ± 198 vs 2nd visit – 141 ± 77 eggs/g; P < 0.01) and the two age groups (Fatteners – 125 ± 71 vs Sows and boars – 419 ± 223 eggs/g; $P < 0.01$). There was no effect of season or age for *Ascaris suum* FEC. Since *Trichuris suis* was found on only two farms it was not statistically analysed.

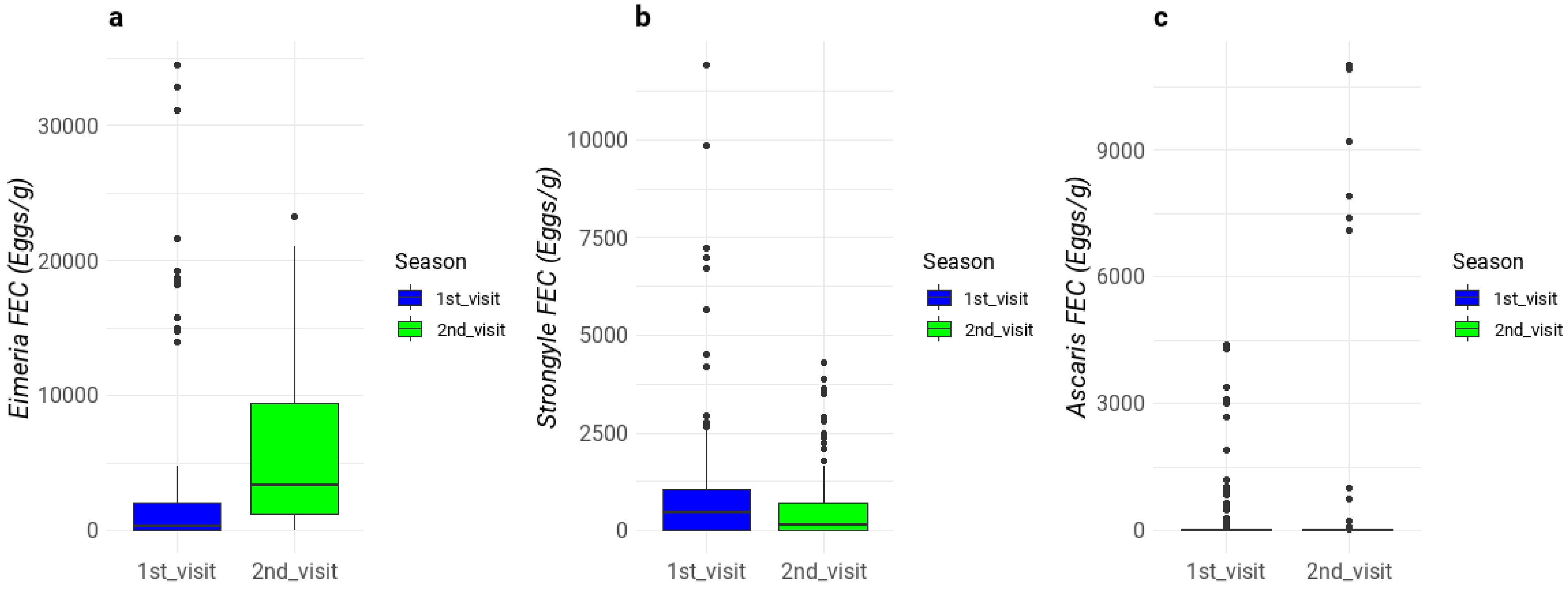

Figure 3.3 – Median and quartiles of (a) *Eimeria spp.*, (b) strongyles and (c) *A. suum* faecal egg counts (FEC) during the 1st (blue) and 2nd visit (green).

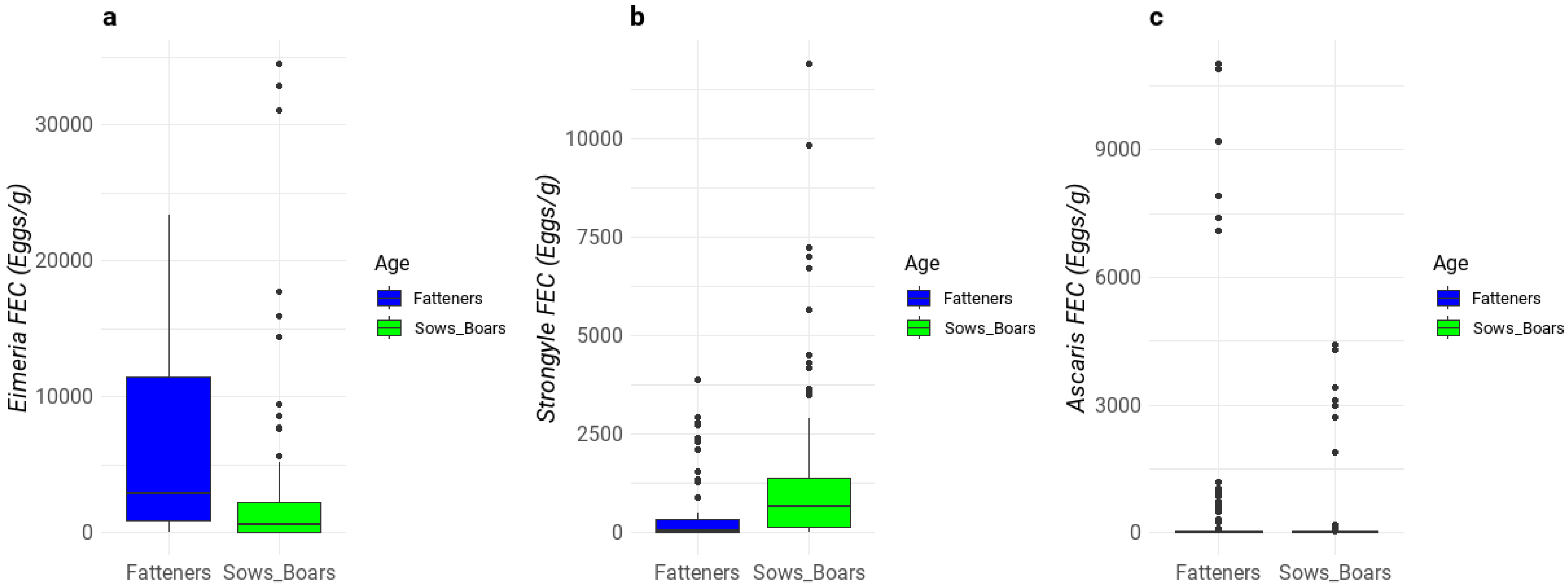

Figure3.4 – Median and quartiles of (a) *Eimeria* spp., (b) strongyles and (c) *A. suum* faecal egg counts in relation to fatteners (blue) and sows/boars (green)

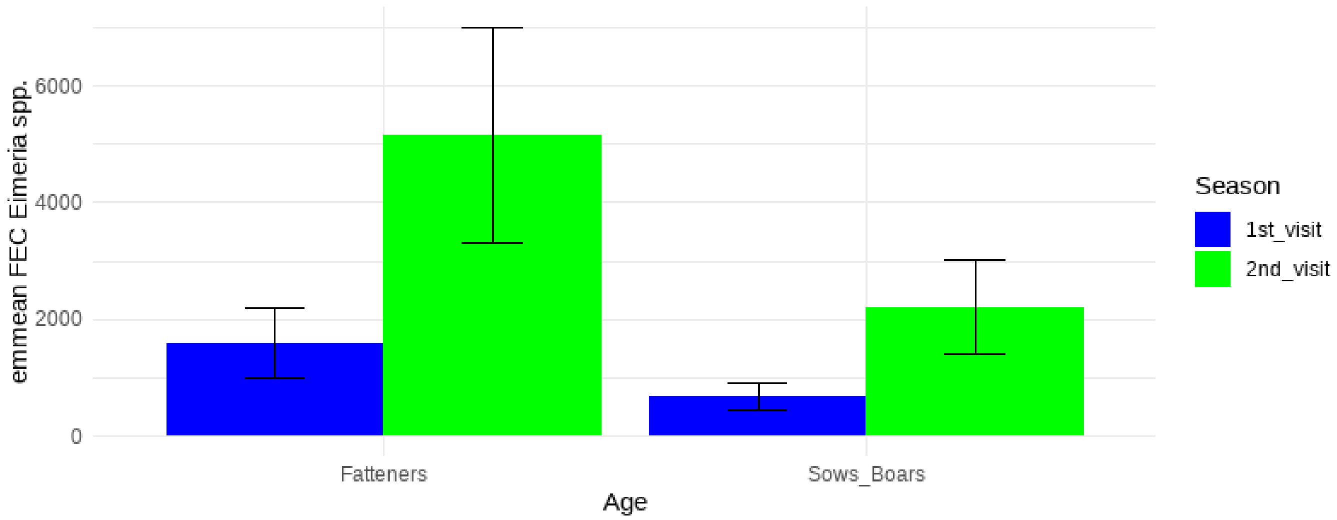

Figure 3.5 – Estimated marginal means for *Eimeria* spp. faecal egg count between fatteners and sows_Boars during the 1st (blue) and 2nd visit (green). Error bars represents standard error

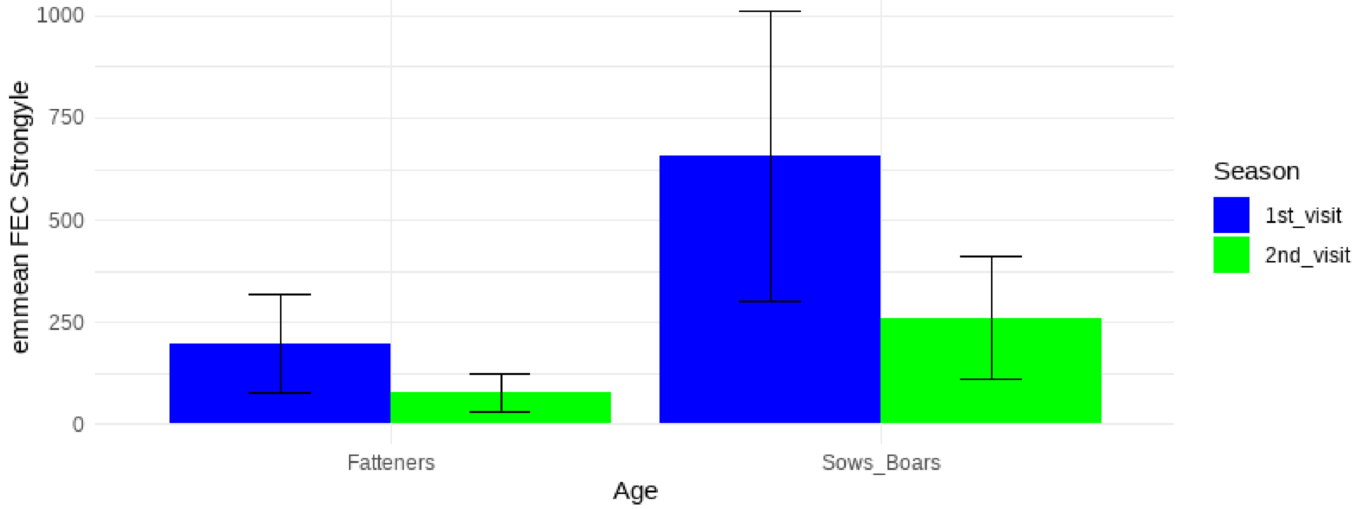

Figure 3.6 - Estimated marginal means for strongyles faecal egg counts between fatteners and sows_Boars during the 1st (blue) and 2nd visit (green).

3.4.4 Effect of using anthelmintics and paddock rotation on faecal egg count

The farms that used anthelmintics had lower strongyle FEC in both seasons (Mean ± SE; Yes – 48.2 ± 37.6 eggs/g, No – 668.3 ± 381.7 eggs/g; P < 0.01). *Ascaris suum* FEC levels did not differ between farms that used or did not use anthelmintics. *Eimeria* spp. were not affected by the usage of anthelmintics. The farms which practiced paddock rotation had lower levels of *Eimeria* spp. FEC when the use of anthelmintics was administered (Mean ± SE; Anthelmintics yes, paddock rotation yes – 1629 ± 651 eggs/g vs Anthelmintics yes, paddock rotation no – 7188 ± 5646 eggs/g; P = 0.05) (Figure 3.7). There was no effect of paddock rotation on *Eimeria* spp., strongyles or on *Ascaris* FEC.

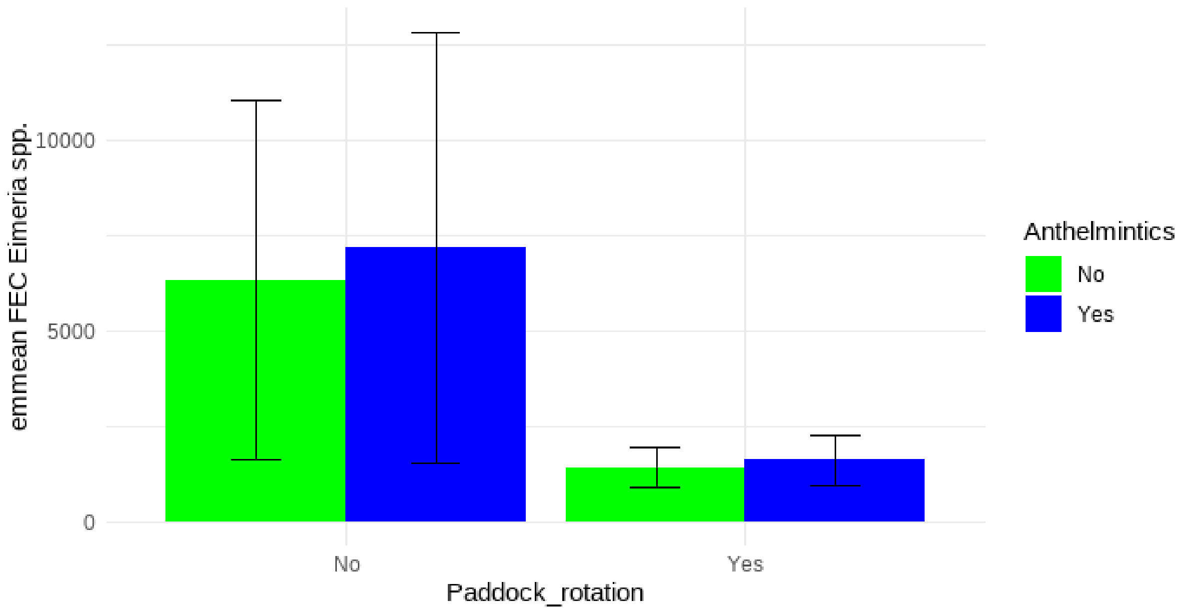

Figure 3.7 - Estimated marginal means for *Eimeria* spp. faecal egg counts for paddock rotation (Yes and No) with anthelmintics use Yes (blue) and No (green).

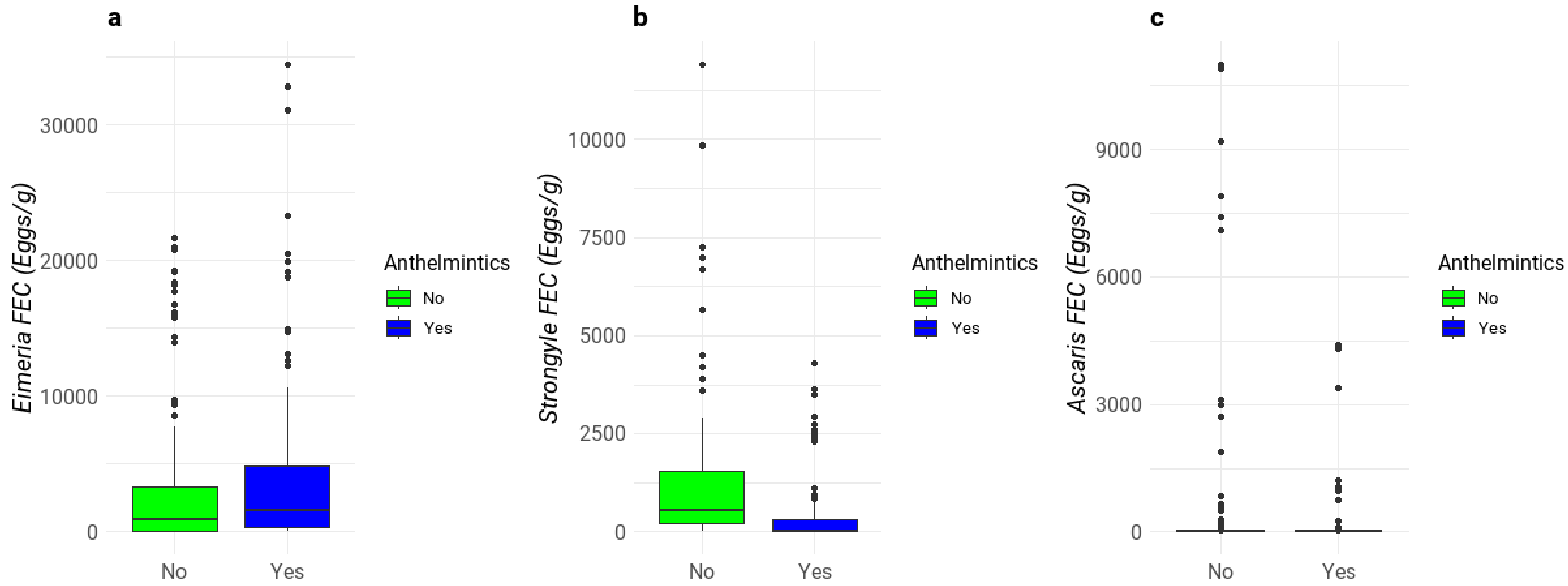

Figure 3.8 – Median and quartiles of (a) *Eimeria* spp., (b) strongyles and (c) *A. suum* in relation to anthelmintic usage (Yes – blue, No – green)

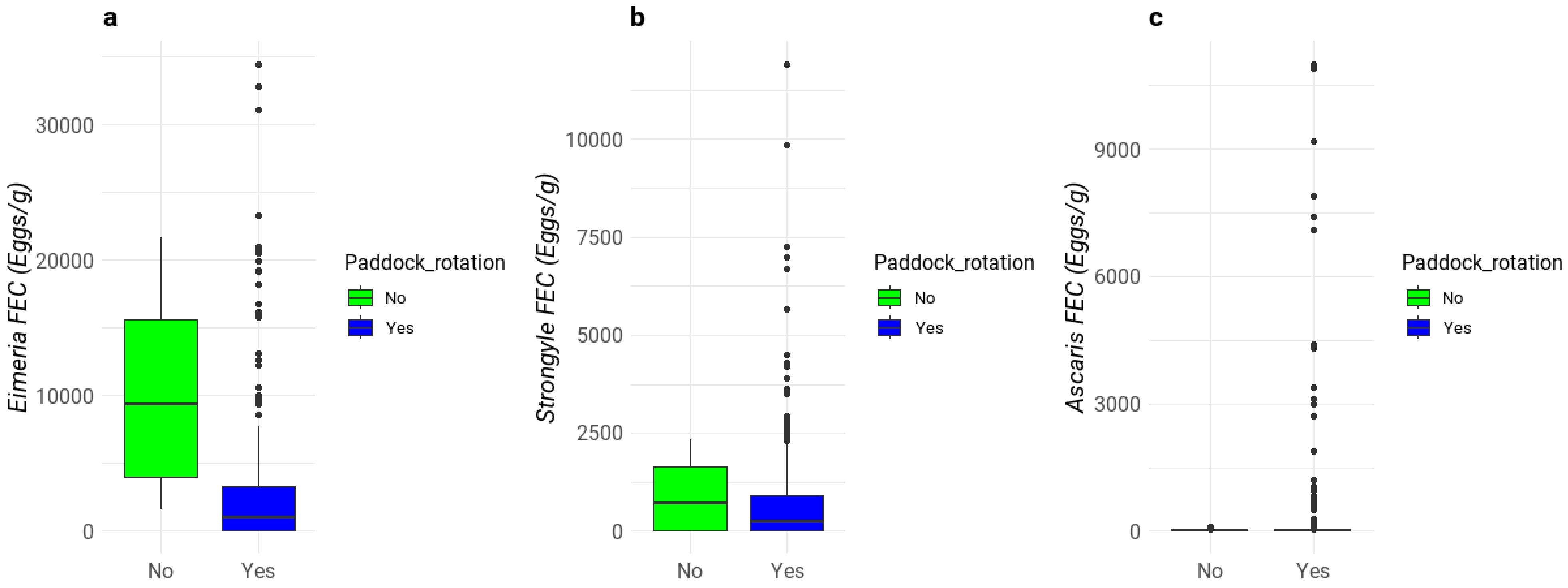

Figure 3.9 – Median and quartiles of (a) *Eimeria* spp., (b) strongyles and (c) *A. suum* in relation to paddock rotation (Yes – blue, No – green)

3.5 Discussion

This study provides the first data on the prevalence of a range of taxa of GI parasites found in pigs produced outdoors in Ireland. The only other work on GI parasites affecting pigs conducted in Ireland looked at liver damage caused by *Ascaris suis* in intensively produced pigs (Rodrigues Da Costa et al., 2020). In the present study, season, age of the pig and the anthelmintic usage had significant effects on FEC related to *Eimeria* spp. and strongyles.

3.5.1 Prevalence of the parasites

A high proportion (>80%) of the farms were affected by *Eimeria* spp*.* and strongyles at both visits. Similarly, a Romanian study found a high prevalence of *Eimeria* spp. during both summer (80%) and winter (77.5%) and for strongyles (*Oesophagostomum* spp*.*), it was 27.5% during summer and 37.5% during winter (Băieş et al., 2022b). In the current study, both *Eimeria* spp. and strongyles were the most prevalent parasite detected over both visits, with prevalence also higher than the values found in Romania.

The high prevalence of the farms affected by *Eimeria* spp. could be due to the *Eimeria* spp. oocyst showing great resistance to environmental conditions, making year round presence possible in the pigs (Chartier & Paraud, 2012). The high prevalence of strongyles could also be due to year round shedding of the eggs by the adult worms. Thus even though the eggs have a low resistance to climatic extremes, compared with other helminth eggs, the possibility of the hatched larvae being ingested is present throughout the year, even while the burden can differ.

Prevalence of *Ascaris suum* (30%) affected farms in our study was more or less similar to some other studies conducted in Europe across all farm systems. *Ascaris suum* had a 28.6% prevalence in Poland, from 70 pig farms (Kochanowski et al., 2017). A study in Estonia found 31.5% prevalence of *Ascaris suum* in ecological and small pig farms (n = 20 farms; Jarvis and Magi, 2007). Free-range farms in Netherlands had a 50% prevalence of *Ascaris suum* (n = 27 farms; Eijck and Borgsteede, 2005). As Rodrigues Da Costa *et al.* (2020) found, 30% of the commercial pig farms in Ireland had pigs with milk spots, which occurs due to *Ascaris suum*. A similar prevalence was recorded in our study, indicating a potential connection across both indoor and outdoor systems.

In the present research, very few farms were affected (one in the 1st visit, 5%, and 2 in the 2nd visit, 12%) by *Trichuris suis* as evidenced by the presence of faecal eggs. In other studies a much higher proportion of farms (ranging from 21.4 to 37.5%) were affected by this parasite (Eijck & Borgsteede, 2005; Kochanowski et al., 2017). However, the relatively quick expulsion of adults, and thus egg-laying individuals, by the host renders the use of FEC alone of little value in assessing prevalence of this helminth species among hosts (Pettersson et al., 2021).

3.5.2 Effect of season and age on the faecal egg count

In research conducted in pigs in intensive systems, Symeonidou et al. (2020) found that *Crisoisospora suis*, a coccidia species similar to *Eimeria* spp., tended to have a lower burden of oocysts in winter compared to spring. Another investigation by Băieş *et al.* (2022b) found the parasitic load of *Eimeria* spp. was different between the seasons winter/spring (higher) and summer/autumn (lower). In our study, the highest mean number of *Eimeria* oocysts was recorded in the second visit, which was during late summer/autumn. *Eimeria* oocysts can die when the temperature is colder (-20 °C) and hotter (38 °C), as in the case of *Eimeria bovis*, a coccidia which infects cows (Lassen *et al.,* 2013). Mild summer temperatures, such as occur in Ireland (mean temperatures between 14 - 15 °C; (Nansen and Roepstorff, 1999: Curley et al., 2023) might result in favourable conditions for the *Eimeria* oocysts to become infective, causing the higher FEC during the summer and autumn month periods. Infection from strongyles occurs from the L3 infective larval stage. Eggs are passed through faeces, hatch, and develop infective larvae, which are ingested by the pigs (Zimmerman et al., 2012). Harsh, cold, winters and dry, hot, summers have detrimental effects on *Oesophagostomum* spp. eggs, leading to higher mortality rates (Mejer et al., 2000). According to Nansen and Roepstorff (1999), the lower temperature limit for the *Oesophagostomum* spp. is ~10 °C and the eggs deposited during the winter do not survive into the spring. Rose and Small (1983) found that transmission of both *Oesophagostomum* spp. and *Hyostrongylus rubidus* could not take place during winter in British conditions. The climatic conditions in Ireland and Britain are more or less similar (Mean temperature 15 to 20 °C). The highest mean faecal egg counts (FEC) of strongyle-type nematodes were observed during the first visit, conducted in late winter/spring. The strongyle lifecycle within the pig spans approximately 4–6 weeks (Taylor et al., 2016). In the environment, most eggs and free-living larvae are eliminated during the winter months due to harsh conditions. This results in a reduced larval load available for ingestion by pigs, leading to fewer mature adult worms and consequently lower FEC during the summer/autumn months. However, Ireland's mild summers, compared to other European countries, may not significantly affect the survival of eggs and free-living larvae. This could contribute to the higher FEC observed during the winter/spring period, as larvae surviving through the summer are ingested by pigs and develop into adult worms capable of producing eggs during these colder months.

The eggs of *Ascaris suum* and *Trichuris suis* are more resistant to environmental conditions, thus improving their longevity (Roepstorff & Murrell, 1997). During our study, the faecal egg counts did not differ between the two visits, although they were present on only 30% of the farms visited.

Several studies mention significant differences in the FEC between pigs of different ages in terms of *Eimeria* spp. and strongyles (Băieş et al., 2022b; Delsart et al., 2022). In our study, fattener pigs had higher mean FEC for *Eimeria* spp. while the sows and boars had higher mean FEC for strongyles. It is noted that older animals (sows and boars) have stronger immunity towards *Eimeria* spp. due to frequent contact with *Eimeria* spp. and other coccidia (Delsart et al., 2022). This could explain the lower FEC in these older animals. In contrast, the pattern for strongyles such as *Oesophagostomum spp.* and *Hyostrongylus rubidus* is similar with higher parasite intensity with increasing host age (Carstensen et al., *2002)*. *Oesophagostomum* spp. has low immunogenicity, resulting in almost all larvae surviving into maturity and living inside the pig for 2 – 4 months (Roepstorff et al., 2011). This could be the reason for the higher strongyles FEC observed during our study in these older animals.

In contrast, *Ascaris suum* and *Trichuris suis* have high immunogenicity and a large majority of larvae are expelled from the small intestine, leaving a small number of mature worms inside the animal (Roepstorff et al., 2011) . The results of our study did not indicate an age difference in FEC; however, in several studies from other European countries the prevalence and intensity of *A. suum* and *T. suis* differed across age groups (intensity lowered with the age of the animal) (Carstensen et al., 2002; Jarvis and Magi, 2009).

3.5.3 Effect of using anthelmintics and paddock rotation on the FEC

Ireland, being a member of the European Union, has a list of approved anthelmintics for use in pigs. In our study, only 7 of the 20 farms administered anthelmintics to their pigs. As the results indicated, the farms which used anthelmintics had significantly lower strongyle counts). Indeed, the use of anthelmintics on strongyle species such as *Oesophagostomum* spp. is highly effective, even though anthelmintic resistance is an emerging issue (Roepstorff et al., 1987; Pettersson et al., 2021). Studies show high efficacy (in some studies >90%) of anthelmintics on *Ascaris suum*, regardless of the class used (Boes et al., 2010; Pettersson et al., 2021). Nevertheless, in our study we did not find a significant difference in the FEC of *Ascaris suum* between farms that did/did not use anthelmintics. However, only 3 of the 7 farms used anthelmintics had *Ascaris suum,* which might have affected the sensitivity of the analysis. In the case of organic farms, the organic standards prohibits the routine usage of anthelmintics unless in a severe clinical cases. Organic farming systems can yield higher numbers of GI parasites (Thamsborg et al., 1999). Our study also included organic farms and all of them did not administer routine anthelmintics to the pigs, and this might have affected the analysis and contribute to the high FEC. Organic farming systems can yield higher numbers of GI parasites.

Paddock rotation is an important management method to control parasites. Anthelmintics alone are not effective in the long -run, as parasites and eggs can survive in the soil so re-infection is inevitable. This could explain why in our study, the FEC of *Eimeria* spp. in the farms that practised paddock rotation was low when the use of anthelmintics was taken into account.

Overall, the results indicated that there are GI parasites present in pigs in outdoor Irish farms, and there are seasonal and age effects in the FEC values for different parasites. There is a lack of data on GI parasites in Irish pigs, particularly those kept outdoors, and this study sheds light on the factors that could affect their prevalence.

3.6 Conclusions

We observed seasonal variation in the FEC of *Eimeria* spp. and strongyles, with *Eimeria* spp. levels higher in the spring, and strongyle levels higher in the autumn. Weaner and fattener pigs had higher *Eimeria* spp. counts while sows and boars had higher strongyle counts, indicating different parasite community dynamics in different age groups. Anthelmintic usage seems to be effective against strongyles, and paddock rotation tended to reduce *Eimeria* spp. counts in the presence of anthelmintics. This study forms a basis for further investigations into GI parasites in outdoor pigs in Ireland.

Chapter 04

Discussion and conclusion

4.0 Discussion and conclusions

4.1 Discussion

This study offers the first comprehensive evaluation of welfare indicators, environmental parameters, and farmer well-being in outdoor pig production systems in Ireland. It focuses on the effects of seasonality, age, and management practices while exploring the interconnections between the three components of 'One Welfare': animal welfare, environmental health, and farmer well-being. The results discussed in the previous chapters highlight the complex interplay within the 'One Welfare' framework, contributing to a holistic understanding of the factors influencing outdoor pig farming.

The findings revealed that most animals had favourable welfare scores across the measured indicators. The majority exhibited good body condition scores (BCS), no signs of lameness, and no tail lesions. These results align with studies conducted on organic and outdoor pig systems in other European countries, which also reported positive welfare outcomes in most animals (Guy et al., 2002; Leeb et al., 2019). Principal Component Analysis showed that the largest proportion of paddocks belonged to Cluster 3, where animal welfare indicators were at optimal levels. This cluster also exhibited high farmer well-being scores, suggesting a positive alignment between improved animal welfare and enhanced human well-being. Comparing with the Irish conventional pig systems, Van Staaveren et al. (2017) found higher prevalence of injurious behaviours, such as ear lesions and tail lesions, however in our case, pigs with tail lesions were quite low. The reasons for these low occurrences is likely to be because of the freedom to express natural behaviours in the outdoor pig farms.

Seasonal variations in welfare indicators were evident, with winter and early spring associated with increased lameness, lice prevalence, and lower BCS. Conversely, summer and early autumn were marked by a higher prevalence of skin lesions and tail lesions, highlighting the impact of weather in Ireland on animal welfare. Although these seasonal effects were statistically significant, the overall proportion of animals with poor welfare scores remained low. However, outdoor pig producers in Ireland could benefit from implementing improved management strategies during extreme seasons (e.g., winter and summer), to further reduce the number of animals with compromised welfare (e.g. – pigs with lower BCS, higher lameness scores).

Age also played a significant role in animal welfare. Older animals, such as sows and boars, had poorer scores for lameness, lice prevalence, and skin lesion counts. As animals age, their susceptibility to adverse conditions increases, and their resilience to environmental challenges may decline (Colditz & Hine, 2016). Producers should prioritize improved management practices for sows and boars to address these vulnerabilities.

PCA further elaborated the impact of age on welfare outcomes. Paddocks with sows and boars were more commonly associated with clusters characterized by low animal welfare scores, reflecting lower averages across most welfare indicators. This finding suggests that management practices for sows and boars differ from those for fattening pigs, potentially leading to sows/boars being overlooked. However, not all paddocks with sows and boars fell into this low-welfare cluster, indicating variability in management practices across farms.

Environmental measures were taken on soil structure and compaction by taking soil shear strength and the number of plants to account for the plant species diversity. Different areas in the paddock revealed different shear strength value, compared to the outside of the paddock, but the loss of soil structure was most prominent in the foraging area of the paddock during summer/autumn. The plant species richness in foraging area was also reduced in the summer period, possibly indicating the high removal by the pigs for consumption. While providing insights into the environment of the outdoor pig farms, these measures were superficial and do not paint a complete picture of the environment. The plant species counted in the paddock are yet to be identified, and once identified, could provide more information on the plant diversity and could further develop into finding preference of certain plant species by pigs. More environmental measurements could be accounted for during the farm visits, however these were not evaluated in the present study, due to the limited time available for a farm assessment during the day. More environmental measurements including soil pH, soil nutrient content, soil microbiome and water quality would provide a more complete picture of the environment in an outdoor pig farm, and these could be used in future studies. Soil nematode diversity could also be considered as an indicator of the environment as the community of soil nematodes indicate the condition of the soil eco – system (Bongers, 1999). The PCA revealed that cluster 2 was where the best animal welfare was recorded, the soil structure was most damaged, with lowest plant species reduction, indicating higher rooting episodes with higher foraging. Cluster 1, where lowest animal welfare was found, had higher soil compaction and higher number of plant species available in the paddock, and this could be indicating lower rooting with lower foraging. Since the plant species are not identified, the plants inside the paddocks in two clusters could be different.

The well-being scores of the farmers was lowest in cluster 2, where the highest animal welfare scores were found. In comparison, higher farmer well-being scores were found in cluster 1 where the lowest animal welfare was found. One welfare framework predicts that human welfare is connected with animal welfare and studies have shown found that poor animal welfare is linked with poor human welfare and vice versa (Devitt et al., 2015; Devitt & Anneberg, 2023). However, the results for our study tells otherwise that even with high human welfare, the animal welfare could be poor. Cluster 2 represented paddocks with farms where they were providing alternative source of feed, as they were organic or genetically-modified free. The low scores could reflect the lack of support from the authorities and the frustration that the famers are facing, as found by Brajon et al. (2024). Cluster 3 showed good levels of well-being scores and it had the most number of paddocks (20).

Faecal egg counts on the studied farms revealed four types of parasite eggs/oocysts; *Eimeria* spp., strongyles, *Ascaris suum* and *Trichuris suis*. The high prevalence levels of *Eimeria* spp. and strongyles during both visits revealed that these two types were present regardless of season. However, the egg count revealed seasonal variations as *Eimeria* spp. counts were higher during summer/autumn months and strongyles counts were high during winter/spring months. Farms that used anthelmintics succeeded in reducing strongyle counts and farms that used anthelmintics and practiced paddock rotation managed to reduce *Eimeria* spp. counts. Our results were in line with other studies in terms of seasonal variations (Băieş et al., 2022b; Toivo & Erika, 2009). Age again played a role in the parasite egg burden as sows/boars had more counts of strongyles and fatteners had more *Eimeria* spp. counts. Although the parasite prevalence was high, producers could benefit from the results, as now they have an understanding of the types and the counts of parasites, hence they will be able to plan the type of treatment for the gastro – intestinal parasites. There was an egg type of structure found on one farm during the 2nd visit which resembled *Macracanthorhynchuss* spp. egg however this was not further investigated since it was found only once. There are plans to carry out metabarcoding study to identify and analyse the GI nematodes in outdoor pigs to further improve the understanding on parasites and this would provide precise information on the parasite taxa.

The overall results imply the effect of season on the welfare of animals, environment and the parasite counts. The pig producers could use these results to better plan the management of the animals considering each seasonal variation and the effect on the animal and the environment. At the same time, the management methods can be tailored for the needs of the animals in different age groups, as shown in the welfare indicators. Welfare of the sows could especially be given special consideration. The control methods for gastro – intestinal parasites could be planned with seasonal occurrences in mind and anthelmintic treatment could be administered with practicing paddock rotation with regular intervals.

4.2 Conclusion

This study provided the first cross sectional view of the welfare of pigs, gastro – intestinal parasites and selected environmental measurements. The majority of the assessed animals had good welfare indicators and low scores, with a small percentage of pigs having poor welfare scores. Seasonal variations were observed in some welfare indicators and gastro - intestinal parasite egg counts. BCS, lameness score and lice prevalence were higher in the 1st visit (winter/early spring) while skin lesions were significant in the 2nd visit (summer/early autumn). The selected environmental measurements saw weakened soil structure and a lower number of plant species in the foraging area in the paddock during the 2nd visit compared to the 1st visit. The relationship between the welfare indices were in three clusters, where they had distinct characteristics. While providing valuable information on the status of the welfare of the animals and the environment, this study could be improved with the inclusion of more welfare indicators and environmental indicators, to widen the understanding of outdoor pig farming. Consideration of adding more outdoor farms would have improved the accuracy of the data taken from the farms. Based on the results, we could recommend the use of anthelmintics against strongyles as it proved to be effective and farmers could benefit from using anthelmintics with paddock rotation to reduce the GI parasite counts. The positive outcomes of the study can be further evaluated to provide recommendations on the time periods of special management practices on animals and the time periods for paddock rotation and the administration of anthelmintics. The environmental measurements we used during our study could be improved for future studies with protocols for soil, biodiversity and water quality measurements for a more holistic understanding of the environment. As the first study done on outdoor pig farms in Ireland, this study could be used as a baseline for future research in this area. The challenge would be to scale up the outdoor production while keeping the positive outcomes of the welfare. The legislation of Ireland should also be upgraded to include outdoor production systems in terms of general guidelines and welfare.

References

Agriculture and Horticulture Development Board. (2023). *AHDB pig production database 2023*. AHDB.

Ang, H. B. Andy. (2010). Occupational Stress Among the New Zealand Farmers—A Review. *Labour, Employment and Work in New Zealand*. https://doi.org/10.26686/lew.v0i0.1708

Băieş, M.-H., Boros, Z., Gherman, C. M., Spînu, M., Mathe, A., Pataky, S., Lefkaditis, M., & Cozma, V. (2022a). Prevalence of Swine Gastrointestinal Parasites in Two Free-Range Farms from Nord-West Region of Romania. *Pathogens*, *11*(9), 954. https://doi.org/10.3390/pathogens11090954

Băieş, M.-H., Gherman, C., Boros, Z., Olah, D., Vlase, A.-M., Cozma-Petruț, A., Györke, A., Miere, D., Vlase, L., Crișan, G., Spînu, M., & Cozma, V. (2022b). The Effects of *Allium sativum* L., *Artemisia absinthium* L., *Cucurbita pepo* L., *Coriandrum sativum* L., *Satureja hortensis* L. and *Calendula officinalis* L. on the Embryogenesis of *Ascaris suum* Eggs during an In Vitro Experimental Study. *Pathogens*, *11*(9), 1065. https://doi.org/10.3390/pathogens11091065

Baumgartner, J., Leeb, T., Gruber, T., & Tiefenbacher, R. (2003). Husbandry and Animal Health on Organic Pig Farms in Austria. *Animal Welfare*, *12*(4), 631–635. https://doi.org/10.1017/S0962728600026294

Boes, J., Kanora, A., Havn, K. T., Christiansen, S., Vestergaard-Nielsen, K., Jacobs, J., & Alban, L. (2010). Effect of *Ascaris suum* infection on performance of fattening pigs. *Veterinary Parasitology*, *172*(3–4), 269–276. https://doi.org/10.1016/j.vetpar.2010.05.007

Bondi, G., Peruzzi, E., Macci, C., Masciandaro, G., & Pistoia, A. (2015). Changes in soil organic matter associated with pig rearing: Influence of stocking densities and land gradient on forest soils in central Italy. *Agriculture, Ecosystems & Environment*, *211*, 32–42. https://doi.org/10.1016/j.agee.2015.05.003

Bondoc, O. L. (2011). *Organic Livestock Farming and Breeding toward Food Security of Smallholder Farmers in the Tropics*. CABI.

Bongers, T. (1999). The Maturity Index, the evolution of nematode life history traits, adaptive radiation and cp-scaling. *Plant and soil*, *212*, 13-22.

Boogaard, B. K., Boekhorst, L. J. S., Oosting, S. J., & Sørensen, J. T. (2011). Socio-cultural sustainability of pig production: Citizen perceptions in the Netherlands and Denmark. *Livestock Science*, *140*(1-3), 189-200.

Bornett, H. L. I., Guy, J. H., & Cain, P. J. (2003). Impact of animal welfare on costs and viability of pig production in the UK. *Journal of Agricultural and Environmental Ethics*, *16*, 163-186.

Brajon, S., Tallet, C., Merlot, E., & Lollivier, V. (2024). Barriers and drivers of farmers to provide outdoor access in pig farming systems: A qualitative study. *Animal*, *18*(5), 101138. https://doi.org/10.1016/j.animal.2024.101138

Brooks, M., E., Kristensen, K., Benthem, K., J. ,van, Magnusson, A., Berg, C., W., Nielsen, A., Skaug, H., J., Mächler, M., & Bolker, B., M. (2017). glmmTMB Balances Speed and Flexibility Among Packages for Zero-inflated Generalized Linear Mixed Modeling. *The R Journal*, *9*(2), 378. https://doi.org/10.32614/RJ-2017-066

Broom, D. M. (1986). Indicators of poor welfare. *British Veterinary Journal*, *142*(6), 524–526. https://doi.org/10.1016/0007-1935(86)90109-0

Broom, D. M. (2014). *Sentience and animal welfare*. Cabi.

Carstensen, L., Vaarst, M., & Roepstorff, A. (2002). Helminth infections in Danish organic swine herds. *Veterinary Parasitology*, *106*(3), 253–264. https://doi.org/10.1016/S0304-4017(02)00080-8

Charlier, J., Rinaldi, L., Musella, V., Ploeger, H. W., Chartier, C., Vineer, H. R., Hinney, B., Von Samson-Himmelstjerna, G., Băcescu, B., Mickiewicz, M., Mateus, T. L., Martinez-Valladares, M., Quealy, S., Azaizeh, H., Sekovska, B., Akkari, H., Petkevicius, S., Hektoen, L., Höglund, J., … Claerebout, E. (2020). Initial assessment of the economic burden of major parasitic helminth infections to the ruminant livestock industry in Europe. *Preventive Veterinary Medicine*, *182*, 105103. https://doi.org/10.1016/j.prevetmed.2020.105103

Chartier, C., & Paraud, C. (2012). Coccidiosis due to Eimeria in sheep and goats, a review. *Small Ruminant Research*, *103*(1), 84–92. https://doi.org/10.1016/j.smallrumres.2011.10.022

Christensen, R. H. B. (2018). Cumulative link models for ordinal regression with the R package ordinal. *Submitted in Journal Staistical. Software*, *35*.

Čobanović, N., Jamnikar-Ciglenečki, U., Kirbiš, A., Križman, M., Štukelj, M., Vićić, I., & Karabasil, N. (2020). Domuzlarda Antemortem Muayenedeki Klinik Bulgular İle Postmortem

Muayenede Belirlenen Patolojik Lezyonların Tutarlılığı. *Kafkas Universitesi Veteriner Fakultesi Dergisi*. https://doi.org/10.9775/kvfd.2020.23884

Colditz, I. G., & Hine, B. C. (2016). Resilience in farm animals: Biology, management, breeding and implications for animal welfare. *Animal Production Science*, *56*(12), 1961. https://doi.org/10.1071/AN15297

Cole, R. J., Litton, C. M., Koontz, M. J., & Loh, R. K. (2012). Vegetation Recovery 16 Years after Feral Pig Removal from a Wet H awaiian Forest. *Biotropica*, *44*(4), 463–471. https://doi.org/10.1111/j.1744-7429.2011.00841.x

Colonius, T. J., & Earley, R. W. (2013). One welfare: A call to develop a broader framework of thought and action. *Journal of the American Veterinary Medical Association*, *242*(3), 309–310. https://doi.org/10.2460/javma.242.3.309

Crawley, J. A. H., Chapman, S. N., Lummaa, V., & Lynsdale, C. L. (2016). Testing storage methods of faecal samples for subsequent measurement of helminth egg numbers in the domestic horse. *Veterinary Parasitology*, *221*, 130–133. https://doi.org/10.1016/j.vetpar.2016.03.012

Curley, M., Coonan, B., Ryan, C., and Ruth, C. E.: Ireland's Climatological Standard Normals (CLINO) 1991-2020, EMS Annual Meeting 2023, Bratislava, Slovakia, 4–8 Sep 2023, EMS2023-517, https://doi.org/10.5194/ems2023-517, 2023.

Damriyasa, I. M., Failing, K., Volmer, R., Zahner, H., & Bauer, C. (2004). Prevalence, risk factors and economic importance of infestations with *Sarcoptes scabiei* and *Haematopinus suis* in sows of pig breeding farms in Hesse, Germany. *Medical and Veterinary Entomology*, *18*(4), 361–367. https://doi.org/10.1111/j.0269-283X.2004.00520.x

Daugschies, a, Meyer, C., & Joachim, a. (1999). Occurrence of Isospora suis in piglet production farms. *Praktische Tierarzt*, *80*, 530-+.

Davis, D. P., & Williams, R. E. (1986). Influence of hog lice, Haematopinus suis, on blood components, behavior, weight gain and feed efficiency of pigs. *Veterinary Parasitology*, *22*(3-4), 307-314.

Day, J. E. L., Kelly, H., Martins, A., & Edwards, S. A. (2003). Towards a Baseline Assessment of Organic Pig Welfare. *Animal Welfare*, *12*(4), 637–641. https://doi.org/10.1017/S0962728600026300

De Lucia, A., Rabie, A., Smith, R. P., Davies, R., Ostanello, F., Ajayi, D., Petrovska, L., & Martelli, F. (2018). Role of wild birds and environmental contamination in the epidemiology of Salmonella infection in an outdoor pig farm. *Veterinary Microbiology*, *227*, 148–154. https://doi.org/10.1016/j.vetmic.2018.11.003

D'Eath, R. B., Arnott, G., Turner, S. P., Jensen, T., Lahrmann, H. P., Busch, M. E., Niemi, J. K., Lawrence, A. B., & Sandøe, P. (2014). Injurious tail biting in pigs: How can it be controlled in existing systems without tail docking? *Animal*, *8*(9), 1479–1497. https://doi.org/10.1017/S1751731114001359

DeBoer, S., Garner, J., McCain, R., Lay, D., Eicher, S., & Marchant-Forde, J. (2015). An initial investigation into the effects of isolation and enrichment on the welfare of laboratory pigs housed in the PigTurn® system, assessed using tear staining, behaviour, physiology and haematology. *Animal Welfare*, *24*(1), 15–27. https://doi.org/10.7120/09627286.24.1.015

Delsart, M., Fablet, C., Rose, N., Répérant, J.-M., Blaga, R., Dufour, B., & Pol, F. (2022). Descriptive Epidemiology of the Main Internal Parasites on Alternative Pig Farms in France. *Journal of Parasitology*, *108*(4). https://doi.org/10.1645/21-126

Delsart, M., Pol, F., Dufour, B., Rose, N., & Fablet, C. (2020). Pig Farming in Alternative Systems: Strengths and Challenges in Terms of Animal Welfare, Biosecurity, Animal Health and Pork Safety. *Agriculture*, *10*(7), 261. https://doi.org/10.3390/agriculture10070261

Devitt, C., & Anneberg, I. (2023). The Interconnection Between Animal and Human Welfare and their Environment. In R. Garcia Pinillos & S. M. H. Canén (Eds.), *One Welfare Animal Health and Welfare, Food Security and Sustainability* (pp. 1–24). CABI. https://doi.org/10.1079/9781789249507.0001

Devitt, C., Kelly, P., Blake, M., Hanlon, A., & More, S. J. (2015). An Investigation into the Human Element of On-farm Animal Welfare Incidents in I reland. *Sociologia Ruralis*, *55*(4), 400–416. https://doi.org/10.1111/soru.12069

Dippel, S., Leeb, C., Bochicchio, D., Bonde, M., Dietze, K., Gunnarsson, S., ... & Prunier, A. (2014). Health and welfare of organic pigs in Europe assessed with animal-based parameters. *Organic Agriculture*, *4*, 149-161.

Donald, A. D. (1994). Parasites, animal production and sustainable development. *Veterinary Parasitology*, *54*(1–3), 27–47. https://doi.org/10.1016/0304-4017(94)90082-5

Edwards, S. A. (1999). Outdoor finishing of pigs. In *Proc 2nd simposio sobre sistema intensivo de suinos criados ao ar livre–SISCAL* (pp. 118-125). EMBRAPA, Concordia, Brasil.

Edwards, S. A. (2003). Intake of nutrients from pasture by pigs. *Proceedings of the Nutrition Society*, *62*(2), 257–265. https://doi.org/10.1079/PNS2002199

Edwards, S. A. (2005). Product quality attributes associated with outdoor pig production. *Livestock Production Science*, *94*(1–2), 5–14. https://doi.org/10.1016/j.livprodsci.2004.11.028

Edwards, S. A., Smith, W. J., Fordyce, C., & MacMenemy, F. (1994). An analysis of the causes of piglet mortality in a breeding herd kept outdoors. *The Veterinary Record*, *135*(14), 324-327.

Eijck, I. A. J. M., & Borgsteede, F. H. M. (2005). A Survey of Gastrointestinal Pig Parasites on Free-range, Organic and Conventional Pig Farms in The Netherlands. *Veterinary Research Communications*, *29*(5), 407–414. https://doi.org/10.1007/s11259-005-1201-z

Eriksen, J., & Kristensen, K. (2001). Nutrient excretion by outdoor pigs: A case study of distribution, utilization and potential for environmental impact. *Soil Use and Management*, *17*(1), 21–29. https://doi.org/10.1111/j.1475-2743.2001.tb00004.x

Etterlin, P. E., Ytrehus, B., Lundeheim, N., Heldmer, E., Österberg, J., & Ekman, S. (2014). Effects of free-range and confined housing on joint health in a herd of fattening pigs. *BMC Veterinary Research*, *10*(1), 208. https://doi.org/10.1186/s12917-014-0208-5

Farm animal welfare advisory council. (2017). Code of practice for the welfare of the pigs. Department of agriculture, food and the Marine, Republic of Ireland.

Firth, H. M., Williams, S. M., Herbison, G. P., & McGee, R. O. (2007). Stress in New Zealand farmers. *Stress and Health*, *23*(1), 51–58. https://doi.org/10.1002/smi.1119

Foata, J., Mouillot, D., Culioli, J.-L., & Marchand, B. (2006). Influence of season and host age on wild boar parasites in Corsica using indicator species analysis. *Journal of Helminthology*, *80*(1), 41–45. https://doi.org/10.1079/JOH2005329

Food and Agriculture Organization of the United Nations. (2022). *Pig production database 2021*. FAO.

Food and Agriculture Organization of the United Nations. (2022). *Pig production database 2022*. FAO.

Fox, J., Friendly, G. G., Graves, S., Heiberger, R., Monette, G., Nilsson, H., ... & Suggests, M. A. S. S. (2007). The car package. *R Foundation for Statistical computing*, *1109*, 1431.

Fredrik Carlsson, Peter Frykblom, Carl Johan Lagerkvist, Consumer willingness to pay for farm animal welfare: mobile abattoirs versus transportation to slaughter, *European Review of Agricultural Economics*, Volume 34, Issue 3, September 2007, Pages 321–344, https://doi.org/10.1093/erae/jbm025

Früh, B., Holinger, M., Dippel, S., Bochicchio, D., Edwards, S., Holmes, D., Prunier, A., Illmann, G., Silerova, J., Knop, D., Rudolph, G., & Leeb, C. (n.d.). *Qualitative Assessment of Current Situation and Future Aims by Organic Pig Farmers*.

Geng, Q., Torén, A., & Salomon, E. (2009). Screening the working environment in outdoor pig systems. *Journal of Agricultural Safety and Health*, *15*(3), 283-297.

Gerber, P. J., Hristov, A. N., Henderson, B., Makkar, H., Oh, J., Lee, C., Meinen, R., Montes, F., Ott, T., Firkins, J., Rotz, A., Dell, C., Adesogan, A. T., Yang, W. Z., Tricarico, J. M., Kebreab, E., Waghorn, G., Dijkstra, J., & Oosting, S. (2013). Technical options for the mitigation of direct methane and nitrous oxide emissions from livestock: A review. *Animal*, *7*, 220–234. https://doi.org/10.1017/S1751731113000876

Guy, J. H., Rowlinson, P., Chadwick, J. P., & Ellis, M. (2002). Health conditions of two genotypes of growing-finishing pig in three different housing systems: Implications for welfare. *Livestock Production Science*, *75*(3), 233–243. https://doi.org/10.1016/S0301-6226(01)00327-X

Halberg, N., Hermansen, J. E., Kristensen, I. S., Eriksen, J., Tvedegaard, N., & Petersen, B. M. (2010). Impact of organic pig production systems on CO2 emission, C sequestration and nitrate pollution. *Agronomy for Sustainable Development*, *30*(4), 721–731. https://doi.org/10.1051/agro/2010006

Hansen, B. G., & Østerås, O. (2019). Farmer welfare and animal welfare- Exploring the relationship between farmer's occupational well-being and stress, farm expansion and animal welfare. *Preventive Veterinary Medicine*, *170*, 104741. https://doi.org/10.1016/j.prevetmed.2019.104741

Hansson, I., Hamilton, C., Ekman, T., & Forslund, K. (2000). Carcass Quality in Certified Organic Production Compared with Conventional Livestock Production. *Journal of Veterinary Medicine, Series B*, *47*(2), 111–120. https://doi.org/10.1046/j.1439-0450.2000.00313.x

He, C., You, Y., Wang, D., & Wu, H. (2018). Estimating soil failure due to torsion via vane shear test by varying vane diameter and soil properties. *Soil and Tillage Research*, *177*, 68–78. https://doi.org/10.1016/j.still.2017.12.004

Hemsworth, P. H., Coleman, G. J., Barnett, J. L., & Borg, S. (2000). Relationships between human-animal interactions and productivity of commercial dairy cows. *Journal of Animal Science*, *78*(11), 2821. https://doi.org/10.2527/2000.78112821x

Holinger, M., Früh, B., Stoll, P., Kreuzer, M., & Hillmann, E. (2018). Grass silage for growing-finishing pigs in addition to straw bedding: Effects on behaviour and gastric health. *Livestock Science*, *218*, 50–57. https://doi.org/10.1016/j.livsci.2018.10.012

Honeyman, M. S. (2005). Extensive bedded indoor and outdoor pig production systems in USA: Current trends and effects on animal care and product quality. *Livestock Production Science*, *94*(1–2), 15–24. https://doi.org/10.1016/j.livprodsci.2004.11.029

Honeyman, M., McGlone, J. J., Kliebenstein, J., & Larson, B. (2001). *Outdoor pig production* (No. 10278). Iowa State University, Department of Economics.

Høøk Presto, M., Andersson, H. K., Folestam, S., & Lindberg, J. E. (2008). Activity behaviour and social interactions of pigs raised outdoors and indoors. *Archives Animal Breeding*, *51*(4), 338–350. https://doi.org/10.5194/aab-51-338-2008

Horta, C., Roque, N., Batista, M., & Duarte, A. C. (2022). Multi-Risk Assessment to Evaluate the Environmental Impact of Outdoor Pig Production Areas: A Case Study. *Agronomy*, *12*(8), 1898. https://doi.org/10.3390/agronomy12081898

Hötzel, M. J., Pinheiro Machado F°, L. C., Wolf, F. M., & Costa, O. A. D. (2004). Behaviour of sows and piglets reared in intensive outdoor or indoor systems. *Applied Animal Behaviour Science*, *86*(1–2), 27–39. https://doi.org/10.1016/j.applanim.2003.11.014

Jakobsen, M., Preda, T., Kongsted, A., & Hermansen, J. (2015). Increased Foraging in Outdoor Organic Pig Production—Modeling Environmental Consequences. *Foods*, *4*(4), 622–644. https://doi.org/10.3390/foods4040622

Jemal, D., & Kebede, B. (2016). The study of major parasitic causes of organ condemnation and financial losses in cattle slaughtered at Hawassa Municipal Abattoir, Ethiopia. *Cogent Food & Agriculture*, *2*(1). https://doi.org/10.1080/23311932.2016.1201183

Jensen, T. B., & Toft, N. (2009). Causes of and predisposing risk factors for leg disorders in growing-finishing pigs. *CABI Reviews*, 1–8. https://doi.org/10.1079/PAVSNNR20094010

Johnson, A. K., Morrow-Tesch, J. L., & McGlone, J. J. (2001). Behavior and performance of lactating sows and piglets reared indoors or outdoors. *Journal of Animal Science*, *79*(10), 2571. https://doi.org/10.2527/2001.79102571x

Jolie, R., Bäckström, L., Pinckney, R., & Olson, L. (1998). Ascarid infection and respiratory health in feeder pigs raised on pasture or in confinement. *Swine Health and Production*, *6*(3).

Kagira, J. M., Githigia, S. M., Ng'ang'a, J. C., Kanyari, P. W. N., Maingi, N., & Gachohi, J. M. (2010). Prevalence of gastrointestinal protozoa and association with risk factors in free-range pigs in Kenya. *Journal of Protozoology Research*, *20*(1), 1–9.

Kasprzyk, A., & Walenia, A. (2023). Native Pig Breeds as a Source of Biodiversity—Breeding and Economic Aspects. *Agriculture*, *13*(8), 1528. https://doi.org/10.3390/agriculture13081528

Kilbride, A., Gillman, C., Ossent, P., & Green, L. (2009). Impact of flooring on the health and welfare of pigs. *In Practice*, *31*(8), 390–395. https://doi.org/10.1136/inpract.31.8.390

Kim, S. W., Gormley, A., Jang, K. B., & Duarte, M. E. (2024). — Invited Review — Current status of global pig production: An overview and research trends. *Animal Bioscience*, *37*(4), 719–729. https://doi.org/10.5713/ab.23.0367

Kipper, M., Andretta, I., Monteiro, S. G., Lovatto, P. A., & Lehnen, C. R. (2011). Meta-analysis of the effects of endoparasites on pig performance. *Veterinary Parasitology*, *181*(2–4), 316–320. https://doi.org/10.1016/j.vetpar.2011.04.029

Kling-Eveillard, F., Dockès, A., & Souquet, C. (2007). Attitudes of French pig farmers towards animal welfare. *British Food Journal*, *109*(11), 859–869. https://doi.org/10.1108/00070700710835679

Knage-Rasmussen, K. M., Houe, H., Rousing, T., & Sørensen, J. T. (2014). Herd- and sow-related risk factors for lameness in organic and conventional sow herds. *Animal*, *8*(1), 121–127. https://doi.org/10.1017/S1751731113001900

Knecht, D., Popiołek, M., & Zaleśny, G. (2011). Does meatiness of pigs depend on the level of gastro-intestinal parasites infection? *Preventive Veterinary Medicine*, *99*(2–4), 234–239. https://doi.org/10.1016/j.prevetmed.2011.01.009

Kochanowski, M., Karamon, J., Dąbrowska, J., Dors, A., Czyżewska-Dors, E., & Cencek, T. (2017). Occurrence of intestinal parasites in pigs in Poland—The influence of factors related to the production system. *Journal of Veterinary Research*, *61*(4), 459–466. https://doi.org/10.1515/jvetres-2017-0053

Kongsted, H., & Sørensen, J. T. (2017). Lesions found at routine meat inspection on finishing pigs are associated with production system. *The Veterinary Journal*, *223*, 21–26. https://doi.org/10.1016/j.tvjl.2017.04.016

Köppel, C., Knopf, L., Ryser, M.-P., Miserez, R., Thür, B., & Stärk, K. D. C. (2007). Serosurveillance for selected infectious disease agents in wild boars (Sus scrofa) and outdoor pigs in Switzerland. *European Journal of Wildlife Research*, *53*(3), 212–220. https://doi.org/10.1007/s10344-006-0080-0

Krystallis, A., De Barcellos, M. D., Kügler, J. O., Verbeke, W., & Grunert, K. G. (2009). Attitudes of European citizens towards pig production systems. *Livestock Science*, *126*(1–3), 46–56. https://doi.org/10.1016/j.livsci.2009.05.016

Lans, C., Turner, N., Khan, T., & Brauer, G. (2007). Ethnoveterinary medicines used to treat endoparasites and stomach problems in pigs and pets in British Columbia, Canada. *Veterinary Parasitology*, *148*(3–4), 325–340. https://doi.org/10.1016/j.vetpar.2007.06.014

Larsen, M. L. V., Gustafsson, A., Marchant, J. N., & Valros, A. (2019). Tear staining in finisher pigs and its relation to age, growth, sex and potential pen level stressors. *Animal*, *13*(8), 1704–1711. https://doi.org/10.1017/S1751731118003646

Lassen, B., Lepik, T., & Bangoura, B. (2013). Persistence of Eimeria bovis in soil. *Parasitology Research*, *112*(7), 2481–2486. https://doi.org/10.1007/s00436-013-3413-4

Lawlor, P. G., & Lynch, P. B. (2007). A review of factors influencing litter size in Irish sows. *Irish Veterinary Journal*, *60*(6), 359–366. https://doi.org/10.1186/2046-0481-60-6-359

Leeb, C., Rudolph, G., Bochicchio, D., Edwards, S., Früh, B., Holinger, M., Holmes, D., Illmann, G., Knop, D., Prunier, A., Rousing, T., Winckler, C., & Dippel, S. (2019). Effects of three husbandry systems on health, welfare and productivity of organic pigs. *Animal*, *13*(9), 2025–2033. https://doi.org/10.1017/S1751731119000041

Lindgren, K., Gunnarsson, S., Höglund, J., Lindahl, C., & Roepstorff, A. (2020). Nematode parasite eggs in pasture soils and pigs on organic farms in Sweden. *Organic Agriculture*, *10*(3), 289–300. https://doi.org/10.1007/s13165-019-00273-3

Ludwiczak, A., Skrzypczak, E., Składanowska-Baryza, J., Stanisz, M., Ślósarz, P., & Racewicz, P. (2021). How Housing Conditions Determine the Welfare of Pigs. *Animals*, *11*(12), 3484. https://doi.org/10.3390/ani11123484

Maqbool, I., Wani, Z. A., Shahardar, R. A., Allaie, I. M., & Shah, M. M. (2017). Integrated parasite management with special reference to gastro-intestinal nematodes. *Journal of Parasitic Diseases*, *41*(1), 1–8. https://doi.org/10.1007/s12639-016-0765-6

Martelli, G. (2009). Consumers’ perception of farm animal welfare: An Italian and European perspective. *Italian Journal of Animal Science*, *8*(sup1), 31–41. https://doi.org/10.4081/ijas.2009.s1.31

McGlone, J. (2013). The Future of Pork Production in the World: Towards Sustainable, Welfare-Positive Systems. *Animals*, *3*(2), 401–415. https://doi.org/10.3390/ani3020401

McGlone, J. J. (2001). Farm animal welfare in the context of other society issues: Toward sustainable systems. *Livestock Production Science*, *72*(1–2), 75–81. https://doi.org/10.1016/S0301-6226(01)00268-8

McGregor, M., Willock, J., Dent, B., Deary, I., Gibson, G., Morgan, O., & Grieve, B. (1995). *EDINBURGH STUDY OF DECISION MAKING ON FARMS: LINKS BETWEEN PSYCHOLOGICAL FACTORS AND FARMER DECISION MAKING*.

Mejer, H., Wendt, S., Thomsen, L. E., Roepstorff, A., & Hindsbo, O. (2000). Nose-Rings and Transmission of Helminth Parasites in Outdoor Pigs. *Acta Veterinaria Scandinavica*, *41*(2), 153–165. https://doi.org/10.1186/BF03549647

Mellor, D. (2017). Operational Details of the Five Domains Model and Its Key Applications to the Assessment and Management of Animal Welfare. *Animals*, *7*(8), 60. https://doi.org/10.3390/ani7080060

Met Éireann. (2023). *Rainfall data for Ireland*. Met Éireann.

Menant, O., Mullen, S., Butler, F., Boyle, L., & O'Driscoll, K.,. Characterizing outdoor pig systems in Ireland. Book of Abstracts of the 74th Annual Meeting of the European Federation of Animal Science. https://doi.org/10.3920/978-90-8686-936-7

Mendoza-Gómez, M. F., Pulido-Villamarín, A., Barbosa-Buitrago, A., & Aranda-Silva, M. (2015). Presence of gastrointestinal parasites in swine and human of four swine production farms in Cundinamarca- Colombia. *Revista MVZ Cordoba*, *20*, 5014–5027. https://doi.org/10.21897/rmvz.15

Miao, Z. H., Glatz, P. C., & Ru, Y. J. (2004). Review of Production, Husbandry and Sustainability of Free-range Pig Production Systems. *Asian-Australasian Journal of Animal Sciences*, *17*(11), 1615–1634. https://doi.org/10.5713/ajas.2004.1615

Millet, S., Moons, C. P., Van Oeckel, M. J., & Janssens, G. P. (2005). Welfare, performance and meat quality of fattening pigs in alternative housing and management systems: A review. *Journal of the Science of Food and Agriculture*, *85*(5), 709–719. https://doi.org/10.1002/jsfa.2033

Monath, T. P., Kahn, L. H., & Kaplan, B. (2010). One health perspective. *ILAR journal*, *51*(3), 193-198.

Mortensen, B., Ruby, V., Pedersen, B. K., Smidth, J., & Aarestrup Larsen, V. (1994). Outdoor pig production in Denmark. Pig News and Information, 1994, Vol. 15, No. 4, 117N-120N ref. 6

Nakamura, K., Tanaka, T., Nishida, K., & Uetake, K. (2011). Behavioral indexes of piglet welfare: Comparison of indoor and outdoor housing systems. *Animal Science Journal*, *82*(1), 161–168. https://doi.org/10.1111/j.1740-0929.2010.00806.x

Nansen, P., & Roepstorff, A. (1999). Parasitic helminths of the pig: Factors influencing transmission and infection levels. *International Journal for Parasitology*, *29*(6), 877–891. https://doi.org/10.1016/S0020-7519(99)00048-X

Nejsum, P., Betson, M., Bendall, R. P., Thamsborg, S. M., & Stothard, J. R. (2012). Assessing the zoonotic potential of *Ascaris suum* and *Trichuris suis*: Looking to the future from an analysis of the past. *Journal of Helminthology*, *86*(2), 148–155. https://doi.org/10.1017/S0022149X12000193

Nota, G., Berretti, R., Ascoli, D., Barberis, D., Ravetto Enri, S., Pittarello, M., Motta, R., Battaglini, L. M., Lombardi, G., & Lonati, M. (2023). Plant species selection and impact on tree resprouts by semi-free ranging pigs in a temperate deciduous forest. *Agroforestry Systems*, *97*(1), 121–132. https://doi.org/10.1007/s10457-022-00792-1

Olczak, K., Nowicki, J., & Klocek, C. (2015). Pig behaviour in relation to weather conditions-A review. *Annals of Animal Science*, *15*(3), 601.

Oravainen, J., Heinonen, M., Seppä-Lassila, L., Orro, T., Tast, A., Virolainen, J., & Peltoniemi, O. (2006). Factors Affecting Fertility in Loosely Housed Sows and Gilts: Vulvar Discharge Syndrome, Environment and Acute-phase Proteins. *Reproduction in Domestic Animals*, *41*(6), 549–554. https://doi.org/10.1111/j.1439-0531.2006.00713.x

Organisation for Economic Co-operation and Development. (2022). *OECD agriculture and livestock database*. OECD.

Ottosen, M., Mackenzie, S. G., Filipe, J. A. N., Misiura, M. M., & Kyriazakis, I. (2021). Changes in the environmental impacts of pig production systems in Great Britain over the last 18 years. *Agricultural Systems*, *189*, 103063. https://doi.org/10.1016/j.agsy.2021.103063

Park, H.-S., Min, B., & Oh, S.-H. (2017). Research trends in outdoor pig production—A review. *Asian-Australasian Journal of Animal Sciences*, *30*(9), 1207–1214. https://doi.org/10.5713/ajas.17.0330

Parkes, J. P., Easdale, T. A., Williamson, W. M., & Forsyth, D. M. (2015). Causes and consequences of ground disturbance by feral pigs (Sus scrofa) in a lowland New Zealand conifer–angiosperm forest. *New Zealand Journal of Ecology*, *39*(1).

Perry, B. D., & Randolph, T. F. (1999). Improving the assessment of the economic impact of parasitic diseases and of their control in production animals. *Veterinary Parasitology*, *84*(3–4), 145–168. https://doi.org/10.1016/S0304-4017(99)00040-0

Pettersson, E., Sjölund, M., Wallgren, T., Lind, E. O., Höglund, J., & Wallgren, P. (2021). Management practices related to the control of gastrointestinal parasites on Swedish pig farms. *Porcine Health Management*, *7*(1), 12. https://doi.org/10.1186/s40813-021-00193-3

Pietrosemoli, S., & Tang, C. (2020). Animal Welfare and Production Challenges Associated with Pasture Pig Systems: A Review. *Agriculture*, *10*(6), 223. https://doi.org/10.3390/agriculture10060223

Pinillos, R. G. (Ed.). (2018). *One welfare: A framework to improve animal welfare and human well-being*. CAB international.

Pinillos, R. G., Appleby, M. C., Manteca, X., Scott-Park, F., Smith, C., & Velarde, A. (2016). One Welfare – a platform for improving human and animal welfare. *Veterinary Record*, *179*(16), 412–413. https://doi.org/10.1136/vr.i5470

Pittman JS, Shepherd G, Thacker BJ, Myers GH, Francisco CJ. [a] Prevalence of internal parasites in a production system: Part I - Sows. Proc 21st IPVS. Vancouver, Canada. 2010;806.

Popiołek, M., Knecht, D., Boruta, O., & Kot, M. (2009). Effect of breeding conditions, phenology, and age on the occurrence of helminths in pigs. A preliminary study. *Bulletin of the Veterinary Institute in Pulawy*, *53*(2), 213–220.

Potterton, S. L., Bell, N. J., Whay, H. R., Berry, E. A., Atkinson, O. C. D., Dean, R. S., Main, D. C. J., & Huxley, J. N. (2012). A descriptive review of the peer and non-peer reviewed literature on the treatment and prevention of foot lameness in cattle published between 2000 and 2011. *The Veterinary Journal*, *193*(3), 612–616. https://doi.org/10.1016/j.tvjl.2012.06.040

Proctor, C., & Hopkins, N. (2023). Stressors and Coping Strategies in Rural Farmers: A Qualitative Study. *Journal of Agromedicine*, *28*(3), 415–424. https://doi.org/10.1080/1059924X.2023.2173691

Prunier, A., Brillouët, A., Merlot, E., Meunier-Salaün, M. C., & Tallet, C. (2013). Influence of housing and season on pubertal development, boar taint compounds and skin lesions of male pigs. *Animal*, *7*(12), 2035–2043. https://doi.org/10.1017/S1751731113001596

Pugliese, C., Calagna, G., Chiofalo, V., Moretti, V. M., Margiotta, S., Franci, O., & Gandini, G. (2004). Comparison of the performances of Nero Siciliano pigs reared indoors and outdoors: 2. Joints composition, meat and fat traits. *Meat Science*, *68*(4), 523–528. https://doi.org/10.1016/j.meatsci.2004.02.020

Pun, I., Galdos, M. V., Chapman, P. J., Lloyd, I. L., Banwart, S., Dobbie, S., & Collins, L. (2024). Measuring and modelling the impact of outdoor pigs on soil carbon and nutrient dynamics under a changing climate and different management scenarios. *Soil Use and Management*, *40*(1), e13029. https://doi.org/10.1111/sum.13029

Quintern, M., & Sundrum, A. (2006). Ecological risks of outdoor pig fattening in organic farming and strategies for their reduction—Results of a field experiment in the centre of Germany. *Agriculture, Ecosystems & Environment*, *117*(4), 238–250. https://doi.org/10.1016/j.agee.2006.04.001

Rangstrup-Christensen, L., Krogh, M. A., Pedersen, L. J., & Sørensen, J. T. (2018). Sow level risk factors for early piglet mortality and crushing in organic outdoor production. *Animal*, *12*(4), 810–818. https://doi.org/10.1017/S1751731117002178

Renaudeau, D., Collin, A., Yahav, S., De Basilio, V., Gourdine, J. L., & Collier, R. J. (2012). Adaptation to hot climate and strategies to alleviate heat stress in livestock production. *Animal*, *6*(5), 707–728. https://doi.org/10.1017/S1751731111002448

Rodrigues Da Costa, M., Fitzgerald, R. M., Manzanilla, E. G., O'Shea, H., Moriarty, J., McElroy, M. C., & Leonard, F. C. (2020). A cross-sectional survey on respiratory disease in a cohort of Irish pig farms. *Irish Veterinary Journal*, *73*(1), 24. https://doi.org/10.1186/s13620-020-00176-w

Roepstorff, A., Mejer, H., Nejsum, P., & Thamsborg, S. M. (2011). Helminth parasites in pigs: New challenges in pig production and current research highlights. *Veterinary Parasitology*, *180*(1–2), 72–81. https://doi.org/10.1016/j.vetpar.2011.05.029

Roepstorff, A., & Murrell, K. D. (1997). Transmission dynamics of helminth parasites of pigs on continuous pasture: Ascaris suum and Trichuris suis. *International Journal for Parasitology*, *27*(5), 563–572. https://doi.org/10.1016/S0020-7519(97)00022-2

Roepstorff, A., Nilsson, O., Oksanen, A., Gjerde, B., Richter, S. H., Örtenberg, E., Christensson, D., Martinsson, K. B., Bartlett, P. C., Nansen, P., Eriksen, L., Helle, O., Nikander, S., & Larsen, K. (1998). Intestinal parasites in swine in the Nordic countries: Prevalence and geographical distribution. *Veterinary Parasitology*, *76*(4), 305–319. https://doi.org/10.1016/S0304-4017(97)00223-9

Rose, J.H. and Small, A.J., 1983. Observations on the effect of anthelmintic treatment on the transmission of Hyostrongylus rubidus and Oesophagostomum spp. among sows at pasture. *Journal of Helminthology*, *57*(1), pp.1-8.

Rousing, T. (2011). Final report for Project no. 1904. Prevention of selected diseases and parasites in organic pig hreds-by means of HACCP based management and surveillance programme (CorePig).

Rudolph, G., Hörtenhuber, S., Bochicchio, D., Butler, G., Brandhofer, R., Dippel, S., Dourmad, J. Y., Edwards, S., Früh, B., Meier, M., Prunier, A., Winckler, C., Zollitsch, W., & Leeb, C. (2018). Effect of Three Husbandry Systems on Environmental Impact of Organic Pigs. *Sustainability*, *10*(10), 3796. https://doi.org/10.3390/su10103796

Salajpal, K., Karolyi, D., & Luković, Z. (2013). Sanitary aspects of outdoor farming systems. *Acta Agriculturae Slovenica. Suplement*, *4*, 109–117. https://doi.org/10.14720/aas-s.2013.4.19032

Salomon, E., Åkerhielm, H., Lindahl, C., & Lindgren, K. (2007). Outdoor pig fattening at two Swedish organic farms—Spatial and temporal load of nutrients and potential environmental impact. *Agriculture, Ecosystems & Environment*, *121*(4), 407–418. https://doi.org/10.1016/j.agee.2006.11.017

Sato, P., Hötzel, M., & Von Keyserlingk, M. (2017). American Citizens' Views of an Ideal Pig Farm. *Animals*, *7*(8), 64. https://doi.org/10.3390/ani7080064

Satrija, F., Nansen, P., Bjørn, H., Murtini, S. H. E. S., & He, S. (1994). Effect of papaya latex against Ascaris suum in naturally infected pigs. *Journal of Helminthology*, *68*(4), 343-346.

Scott, K., Binnendijk, G. P., Edwards, S. A., Guy, J. H., Kiezebrink, M. C., & Vermeer, H. M. (2009). Preliminary evaluation of a prototype welfare monitoring system for sows and piglets (Welfare Quality® project). *Animal Welfare*, *18*(4), 441-449.

Solaymani-Mohammadi, S., & Petri, W. A. (2006). Zoonotic implications of the swine-transmitted protozoal infections. *Veterinary Parasitology*, *140*(3–4), 189–203. https://doi.org/10.1016/j.vetpar.2006.05.012

Spigarelli, C., Berton, M., Corazzin, M., Gallo, L., Pinterits, S., Ramanzin, M., Ressi, W., Sturaro, E., Zuliani, A., & Bovolenta, S. (2021). Animal Welfare and Farmers' Satisfaction in Small-Scale Dairy Farms in the Eastern Alps: A "One Welfare" Approach. *Frontiers in Veterinary Science*, *8*, 741497. https://doi.org/10.3389/fvets.2021.741497

Spooner, J. M., Schuppli, C. A., & Fraser, D. (2014). Attitudes of Canadian citizens toward farm animal welfare: A qualitative study. *Livestock Science*, *163*, 150–158. https://doi.org/10.1016/j.livsci.2014.02.011

Stolba, A., Baker, N., & Wood-Gush, D. G. M. (1983). The characterisation of stereotyped behaviour in stalled sows by informational redundancy. *Behaviour*, *87*(3-4), 157-182.

Stolba, A., & Wood-Gush, D. G. M. (1989). The behaviour of pigs in a semi-natural environment. *Animal Science*, *48*(2), 419-425.

Studnitz, M., Jensen, M. B., & Pedersen, L. J. (2007). Why do pigs root and in what will they root? *Applied Animal Behaviour Science*, *107*(3–4), 183–197. https://doi.org/10.1016/j.applanim.2006.11.013

Stukenborg, A., Traulsen, I., Stamer, E., Puppe, B., & Krieter, J. (2012). The use of a lesion score as an indicator for agonistic behaviour in pigs. *Archives Animal Breeding*, *55*(2), 163–170. https://doi.org/10.5194/aab-55-163-2012

Symeonidou, I., Tassis, P., Gelasakis, A. I., Tzika, E. D., & Papadopoulos, E. (2020). Prevalence and Risk Factors of Intestinal Parasite Infections in Greek Swine Farrow-To-Finish Farms. *Pathogens*, *9*(7), 556. https://doi.org/10.3390/pathogens9070556

Tarazona, A. M., Ceballos, M. C., & Broom, D. M. (2019). Human Relationships with Domestic and Other Animals: One Health, One Welfare, One Biology. *Animals*, *10*(1), 43. https://doi.org/10.3390/ani10010043

Taylor, M.A., Coop, R.L., Wall, R. L. (2016). Veterinary Parasitology. In *Veterinary Parasitology: Vol. Fourth edi*. Wiley Blackwell.

Teagasc. (2023). National pig herd performance report 2023. Teagasc.

Telkänranta, H., Marchant, J. N., & Valros, A. (2016). Tear staining in pigs: A potential tool for welfare assessment on commercial farms. *Animal*, *10*(2), 318–325. https://doi.org/10.1017/S175173111500172X

Temple, D., Courboulay, V., Manteca, X., Velarde, A., & Dalmau, A. (2012). The welfare of growing pigs in five different production systems: Assessment of feeding and housing. *Animal*, *6*(4), 656–667. https://doi.org/10.1017/S1751731111001868

Thamsborg, S. M., Roepstorff, A., & Larsen, M. (1999). Integrated and biological control of parasites in organic and conventional production systems. *Veterinary parasitology*, *84*(3-4), 169-186.

Thamsborg, S. M., Roepstorff, A., & Larsen, M. (1999). Integrated and biological control of parasites in organic and conventional production systems. *Veterinary Parasitology*, *84*(3–4), 169–186. https://doi.org/10.1016/S0304-4017(99)00035-7

Thomsen, L. E., Mejer, H., Wendt, S., Roepstorff, A., & Hindsbo, O. (2001). The influence of stocking rate on transmission of helminth parasites in pigs on permanent pasture during two consecutive summers. *Veterinary Parasitology*, *99*(2), 129–146. https://doi.org/10.1016/S0304-4017(01)00454-X

Thorslund, C. A. H., Aaslyng, M. D., & Lassen, J. (2017). Perceived importance and responsibility for market-driven pig welfare: Literature review. *Meat Science*, *125*, 37–45. https://doi.org/10.1016/j.meatsci.2016.11.008

Toivo, J., & Erika, M. (2008). Pig endoparasites in Estonia. In *Animals, Health and Food Hygiene. Proceedings of the International Scientific Conference* (pp. 54–58). Jelgava, Latvia, November 14.Tozawa, A., Tanaka, S., & Sato, S. (2016). The Effects of Components of Grazing System on Welfare of Fattening Pigs. *Asian-Australasian Journal of Animal Sciences*, *29*(3), 428–435. https://doi.org/10.5713/ajas.15.0190

Turner, S. P., Farnworth, M. J., White, I. M. S., Brotherstone, S., Mendl, M., Knap, P., Penny, P., & Lawrence, A. B. (2006). The accumulation of skin lesions and their use as a predictor of individual aggressiveness in pigs. *Applied Animal Behaviour Science*, *96*(3–4), 245–259. https://doi.org/10.1016/j.applanim.2005.06.009

Van De Weerd, H. A., & Day, J. E. L. (2009). A review of environmental enrichment for pigs housed in intensive housing systems. *Applied Animal Behaviour Science*, *116*(1), 1–20. https://doi.org/10.1016/j.applanim.2008.08.001

Van Huik, M. M., & Bock, B. B. (2007). Attitudes of Dutch pig farmers towards animal welfare. *British Food Journal*, *109*(11), 879–890. https://doi.org/10.1108/00070700710835697

Van Staaveren, N., Doyle, B., Manzanilla, E. G., Calderón Díaz, J. A., Hanlon, A., & Boyle, L. A. (2017). Validation of carcass lesions as indicators for on-farm health and welfare of pigs. *Journal of Animal Science*, *95*(4), 1528. https://doi.org/10.2527/jas2016.1180

Vaarst, M., Roepstorff, A., Feenstra, A., Høgedal, P., Moustsen, V. A., Lauridsen, H. B., & Hermansen, J. E. (2000). Animal health aspects of organic pig production. In *Proceedings 13th International IFOAM-Scientific Conference, 28-31 August, Basel, Switzerland* (pp. 373-373)

Villettaz Robichaud, M., Rushen, J., De Passillé, A. M., Vasseur, E., Orsel, K., & Pellerin, D. (2019). Associations between on-farm animal welfare indicators and productivity and profitability on Canadian dairies: I. On freestall farms. *Journal of Dairy Science*, *102*(5), 4341–4351. https://doi.org/10.3168/jds.2018-14817

Walker, P. K., & Bilkei, G. (2006). Tail-biting in outdoor pig production. *The Veterinary Journal*, *171*(2), 367–369. https://doi.org/10.1016/j.tvjl.2004.10.011

Wang, C., Li, J., Wei, H., Zhou, Y., Tan, J., Sun, H., Jiang, S., & Peng, J. (2018). Analysis of influencing factors of boar claw lesion and lameness. *Animal Science Journal*, *89*(5), 802–809. https://doi.org/10.1111/asj.12974

Watson, C. A., Atkins, T., Bento, S., Edwards, A. C., & Edwards, S. A. (2003). Appropriateness of nutrient budgets for environmental risk assessment: a case study of outdoor pig production. *European Journal of Agronomy*, *20*(1-2), 117-126.

Webster, A. J. F. (1998). What use is science to animal welfare?. *Naturwissenschaften*, *85*, 262-269.

Wehr, N. H., Kinney, K. M., Nguyen, N. H., Giardina, C. P., & Litton, C. M. (2019). Changes in soil bacterial community diversity following the removal of invasive feral pigs from a Hawaiian tropical montane wet forest. *Scientific Reports*, *9*(1), 14681. https://doi.org/10.1038/s41598-019-48922-7

Whittemore, C.T.,. (2018). Animal farming: The story behind the livestock industry. BRILL.

Whittemore, C. T., & Kyriazakis, I. (2008). *Whittemore's science and practice of pig production*. John Wiley & Sons.

Williams, J. R., Chambers, B. J., Hartley, A. R., & Chalmers, A. G. (2006). Nitrate leaching and residual soil nitrogen supply following outdoor pig farming. *Soil Use and Management*, *21*(2), 245–252. https://doi.org/10.1111/j.1475-2743.2005.tb00131.x

Wooten-Saadi, E. L., Towell-Vail, C. A., Williams, R. E., & Gaafar, S. M. (1987). Incidence of Sarcoptes scabiei (Acari: Sarcoptidae) and Haematopinus suis (Anoplura: Haematopinidae) on Swine in Indiana. *Journal of Economic Entomology*, *80*(5), 1031–1034. https://doi.org/10.1093/jee/80.5.1031

World Bank. (2018). Operational framework for strenghtening human, animal and environmental public health systems at their interface. World Bank Group.

Yonezawa, T., Takahashi, A., Imai, S., Okitsu, A., Komiyama, S., Irimajiri, M., Matsuura, A., Yamazaki, A., & Hodate, K. (2012). Effects of Outdoor Housing of Piglets on Behavior, Stress Reaction and Meat Characteristics. *Asian-Australasian Journal of Animal Sciences*, *25*(6), 886–894. https://doi.org/10.5713/ajas.2011.11380

Zimmerman, J.J. ed., 2012. *Diseases of swine*. John Wiley & Sons.

Appendix

QoL survey questionnaire

Consent form (please tick the boxes below)

- ☐ I agree to participate in this research
- ☐ This agreement is of my own free will
- ☐ I have been given information regarding the aims of the research and have been given the researchers' name and contact details if I require further information
- ☐ I have had the opportunity to ask any questions I want about the study
- ☐ I understand that I may withdraw from the study at any time during testing, without suffering any adverse consequences
- ☐ I am aware that if I can ask to have my data withdrawn from the study by contacting a member of the research team within four weeks after completing the study
- ☐ I understand that all personal information provided by myself will remain confidential and no information that identifies me will be made publicly available

Please enter your name below in BLOCK CAPITALS (first name and surname)

____

Please enter the name of your farm

____

Farm type

- ◯ Conventional indoor pig farm
- ◯ Alternative pig farm (e.g. free range, organic etc.)

What age are you?

____

What is your gender?

- ◯ Male
- ◯ Female
- ◯ Non-binary / third gender
- ◯ Prefer not to say

Is keeping pigs a full time or part time occupation for you?

- ◯ Full time
- ◯ Part time

How many years have you worked in the pig farming industry?

____

You will now be asked a number of questions related to your wellbeing and job satisfaction

---

The following questions ask how you feel about your quality of life, health, or other areas of your life.

Please choose the answer that appears most appropriate. If you are unsure about which response to give to a question, the first response you think of is often the best one.

Please keep in mind your standards, hopes, pleasures and concerns. We ask that you think about your life **in the last four weeks.**

Quality of life

	Very poor	Poor	Neither poor nor good	Good	Very good
How would you rate your quality of life?	○	○	○	○	○

Health satisfaction

	Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
How satisfied are you with your health?	○	○	○	○	○

The following questions ask about **how much** you have experienced certain things in the last four weeks.

	None at all	A little	A moderate amount	Very much	An extreme amount
To what extent do you feel that physical pain prevents you from doing what you need to do?	○	○	○	○	○
How much do you need any medical treatment to function in your daily life?	○	○	○	○	○
How much do you enjoy life?	○	○	○	○	○
To what extent do you feel your life to be meaningful?	○	○	○	○	○

The following questions ask about how much you have experienced certain things in the last four weeks.

	Not at all	A little	A moderate amount	Very much	Extremely
How well are you able to concentrate?	○	○	○	○	○
How safe do you feel in your daily life?	○	○	○	○	○
How healthy is your physical environment?	○	○	○	○	○

The following questions ask about how completely you experience or were able to do certain things in the last four weeks.

	Not at all	A little	Moderately	Mostly	Completely
Do you have enough energy for everyday life?	○	○	○	○	○
Are you able to accept your bodily appearance?	○	○	○	○	○
Have you enough money to meet your needs?	○	○	○	○	○
How available to you is the information that you need in your day-to-day life?	○	○	○	○	○
To what extent do you have the opportunity for leisure activities?	○	○	○	○	○

The following question asks about how completely you experience or were able to do certain things in the last four weeks.

	Very poor	Poor	Neither poor nor good	Good	Very good
How well are you able to get around?	○	○	○	○	○

The following questions ask about how completely you experience or were able to do certain things in the last four weeks.

	Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
How satisfied are you with your sleep?	○	○	○	○	○
How satisfied are you with your ability to perform your daily living activities?	○	○	○	○	○
How satisfied are you with your capacity for work?	○	○	○	○	○
How satisfied are you with yourself?	○	○	○	○	○
How satisfied are you with your personal relationships?	○	○	○	○	○

How satisfied are you with your sex life?	○	○	○	○	○
How satisfied are you with the support you get from your friends?	○	○	○	○	○
How satisfied are you with the conditions of your living place?	○	○	○	○	○
How satisfied are you with your access to health services?	○	○	○	○	○

How satisfied are you with your transport?					

The following question refers to how often you have felt or experienced certain things in the last four weeks.

	Never	Seldom	Quite often	Very often	Always
How often do you have negative feelings such as blue mood, despair, anxiety, depression?					

Do you have any comments about the assessment?

____

Below are some statements about feelings and thoughts.
Please tick the box that best describes your experience of each over **the last 2 weeks**

	None of the time	Rarely	Some of the time	Often	All of the time
I’ve been feeling optimistic about the future	○	○	○	○	○
I've been feeling useful	○	○	○	○	○
I've been feeling relaxed	○	○	○	○	○
I've been feeling interested in other people	○	○	○	○	○
I've had energy to spare	○	○	○	○	○
I've been dealing with problems well	○	○	○	○	○
I've been thinking clearly	○	○	○	○	○

I've been feeling good about myself	○	○	○	○	○
I've been feeling close to other people	○	○	○	○	○
I've been feeling confident	○	○	○	○	○
I've been able to make up my own mind about things	○	○	○	○	○
I've been feeling loved	○	○	○	○	○
I've been interested in new things	○	○	○	○	○
I've been feeling cheerful	○	○	○	○	○

Work satisfaction

	Very satisfied	Satisfied	Dissatisfied	Highly dissatisfied
How satisfied are you with your job as a whole, everything taken into consideration?	○	○	○	○